

# SECOND FIVE-YEAR REVIEW REPORT

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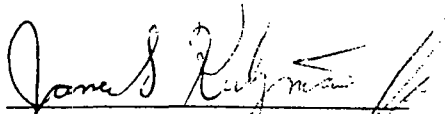
DISTLER BRICKYARD SITE  
CITY OF WEST POINT  
HARDIN COUNTY, KENTUCKY

September 2003

PREPARED BY

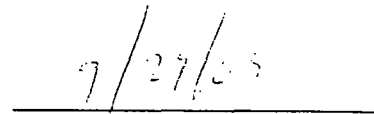
USEPA, REGION 4  
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# DISTLER BRICKYARD FIVE-YEAR REVIEW REPORT

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## List of Acronyms

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CGA	Coarse Grained Alluvium
COC	Contaminants of Concern
EPA	Environmental Protection Agency
ESD	Explanation of Significant Differences
FGA	Fine Grained Alluvium
INEEL	Idaho National Engineering and Environmental Laboratory
KDEP	Kentucky Department for Environmental Protection
KNREPC	Kentucky Natural Resources and Environmental Protection Cabinet
LTRA	Long Term Remedial Action
MCL	Maximum Contaminant Level
MSD	Metropolitan Sewer District
MW	Monitoring Well
NCP	National Contingency Plan
NPL	National Priorities List
O & M	Operations and Maintenance
ppb	parts per billion
RD	Remedial Design
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
TCE	Trichloroethene
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
1,1-DCE	1,1-Dichloroethylene

## EXECUTIVE SUMMARY

The Distler Brickyard Site was discovered by the Commonwealth of Kentucky officials in 1976, and was placed on the NPL for remedial activities in 1982. The decision documents on the site called for soil and groundwater remediation. Soil remediation was accomplished in 1988 and the groundwater cleanup which began in September 1994, is currently in progress as a CERCLA Fund-Financed State-Lead Long-Term Remedial Action.

The first Five-Year Review of the project was conducted in 1998. The review concluded that the remedy implemented at the site was progressing satisfactorily. Several of the contaminants of concern at the site were reported to have been reduced to acceptable concentration levels by the remedial measures at the site. However, the groundwater pump and treat system at the site was reported to be ineffective for the contaminants remaining above their clean-up goals. Therefore, the 1998 review recommended a comprehensive re-evaluation of the site and a determination of new options for expediting the cleanup of the persistent contaminants.

An innovative technology was developed for the site as a result of the re-evaluation by an EPA contractor. The technology combines hydraulic fracturing of the tight aquifer which contains site contaminants with the injection of chitin (i.e, shrimp and crab shells) which, according to laboratory tests, has the ability to enhance biodegradation of contaminants such as those found at this site. Distler Brickyard became the first Superfund site and possibly the first location for field application of the technology when the Pilot test was conducted at the site in October 2001. As a result of successfully testing the technology, it was applied at the site as a full-scale project in April and May 2003, to expedite the LTRA. Both the pilot test and the full scale project were funded primarily by two grants totaling five hundred thousand dollars (\$500,000) received from National Science Foundation because of the innovative nature of the technology.

There are no data at this time to evaluate the performance of the LTRA relative to the bioremediation enhancement efforts. However, based on the field data collected before and after the pilot test, the site is expected to benefit from the recent application of the chitin-fracturing technology. Focused monitoring activities designed to provide the data necessary to evaluate performance of the LTRA carefully are in progress at the site currently. The site is stable and continues to protect human health and the environment.

The main recommendation in this report is to continue the monitoring activities and to ensure that the USGS and North Wind Environmental, Inc. who recently studied the site and are addressing its issues are funded properly so that they can remain as consultants for the site until all clean-up goals are met. Current levels of USEPA and State oversights on the LTRA must be maintained to ensure that it is evaluated regularly and its performance documented properly for the next Five-Year Review and/or any necessary interim decision about its progress.

### Five-Year Review Summary Form

<b>SITE NAME : Distler Brickyard</b>		
<b>EPA ID # : KYD 980602155</b>		
<b>SITE IDENTIFICATION</b>		
<b>REGION: IV</b>	<b>STATE: Kentucky</b>	<b>CITY/COUNTY: West Point /Hardin</b>
<b>SITE STATUS</b>		
<b>NPL STATUS: Active</b>		<b>REMEDATION STATUS: Active</b>
<b>ACTIVITY IN PROGRESS: Long-Term Remedial Action</b>		
<b>HOW MANY Ours ? 1</b>		<b>CONSTRUCTION COMPLETION DATE : 09/15/94</b>
<b>IS THE SITE IN RE-USE? No</b>		
<b>REVIEW STATUS</b>		
<b>LEAD AGENCY: USEPA</b>		
<b>AUTHOR, AFFILIATION &amp; TITLE: Femi Akindele, USEPA, Project Manager</b>		
<b>AUTHOR, AFFILIATION &amp; TITLE: Ken Logsdon, Kentucky Department for Environmental Protection, Project Manager</b>		
<b>PERIOD REVIEWED: 9/98-8/2003</b>		
<b>SITE INSPECTION DATE(S): 8/22/2003</b>		
<b>REVIEW TYPE: Policy</b>		<b>REVIEW NUMBER: 2</b>
<b>TRIGGERING ACTION &amp; DATE: First Five-Year Review ----9/28/98</b>		
<b>REVIEW DUE DATE IN CERCLIS : 9/30/2003</b>		
<b>DATE REVIEW STARTED: 8/14/2003</b>		
<b>DATE REVIEW COMPLETED: 9/26/2003</b>		

#### **Recommendations:**

Continue to monitor the site in light of the recent bioremediation enhancement efforts. EPA and the State should ensure that USGS and North Wind are properly funded to continue providing technical assistance at the site until all clean-up goals are met. Current levels of EPA and State oversight of the LTRA should be maintained to ensure that the project is evaluated regularly and its progress documented properly for the next Five-Year Review and any necessary future decision about the LTRA.

KDEP will continue to be responsible for all site activities and reporting on the foregoing recommendations pursuant to the current Fund-Financed State-Lead Cooperative Agreement for the site. EPA will continue to provide technical support as necessary.

### **Summary Form Cntd.**

**Issues and Deficiencies: None**

**Other Comments: None**

**Protectiveness Statement:**

The remedy implemented at the Distler Brickyard Site currently protects human health and the environment. Many of the COCs at the site have been reduced to acceptable concentration levels. Enhanced remedial measures have been taken to ensure that the remaining COCs are cleaned up rapidly. There are no technical or physical issues related to the site that are likely to reverse its current level of stability and protectiveness of human health and the environment.

**SECOND FIVE-YEAR REVIEW REPORT  
DISTLER BRICKYARD SITE  
HARDIN COUNTY, KENTUCKY**

**I. INTRODUCTION**

The purpose of Five-Year Reviews is to determine if the remedy at a site is protective of human health and the environment. Methods, findings, and conclusions of reviews are documented in Five-Year Review Reports. In addition, the reports identify issues found during the review, if any, and make recommendations to address them.

The Agency has prepared this Five-Year Review pursuant to CERCLA §121 and the National Contingency Plan (NCP). CERCLA §121 states:

“If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgement of the President that action is appropriate at such site in accordance with section 104 or 106, the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.”

The Agency interpreted this requirement further in the NCP; 40 CFR §300.430(f)(4)(ii) states:

“If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.”

This is the second five-year review for the Distler Brickyard Site and it has been conducted as a “policy review” which the Agency conducts at a site until cleanup levels are achieved, allowing unlimited use and unrestricted exposure.

The first Five-Year Review of the site was conducted in 1998. It concluded that the remedy implemented at the site was performing satisfactorily and showed that cleanup goals had been met for some but not all of the contaminants of concern. The review also indicated that the persisting contaminants were being removed slowly by the groundwater treatment process at the site. Therefore, it recommended a comprehensive re-evaluation of the LTRA vis-a-vis site hydrogeology and a study of options needed to enhance the cleanup process. This report presents a review of activities conducted at the site and progress of the LTRA in the last five years. It concludes that the site continues to protect human health and the environment and that the measures taken to enhance the groundwater cleanup as recommended by the last Five Year Review have yielded favorable results.



The current review was conducted by EPA Region 4 in August and September 2003. Support was provided by the Commonwealth of Kentucky, USGS and North Wind Environmental, Inc. It was triggered by the last Five-Year Review which was completed in September 1998.

## II. SITE CHRONOLOGY

TABLE 1: CHRONOLOGY OF EVENTS

EVENT	DATE
Kentucky officials discovered and inspected site	12/76
EPA conducted emergency removal action at the site	3/82
Site ranked and listed on the NPL	1982
RI/FS conducted	4/84-3/86
EPA began enforcement activities	12/85
Proposed Plan public meeting held	4/86
Record of Decision signed	8/86
Remedial Design Activities initiated	4/87
Superfund-State Contract signed	9/28/88
Soil remediation began/Remedial Construction started	9/88
Explanation of Significant Differences completed	10/88
Groundwater Remedial Action initiated	7/89
Remedial Action Construction completed/LTRA started	9/94
Interim Site Close-Out Report signed	1/11/95
USGS Special Monitoring Services started under an IAG	8/95
State-Lead-Fund-Financed Cooperative Agreement for LTRA signed	4/1/96
First Five-Year Review Report Issued	9/28/98
Technical Support from USEPA Las Vegas began	4/99
Enhanced Bioremediation Pilot Test initiated	10/01
Full-Scale Enhanced Bioremediation Construction conducted	4/03-5/03

### **III. BACKGROUND**

#### **Location**

The Distler Brickyard site is located approximately seventeen miles southwest of Louisville, near the City of West Point in Hardin County, Kentucky. The site is a portion of a 70-acre farmland which is divided by Dixie Highway (U.S. Route 60/31W), the western boundary of the site. The Ohio River and Salt River confluence is approximately one mile northwest of the site. Site elevations vary between 418 and 451 feet above sea level and portions of the property are within the 10-year flood plain of the Ohio River.

#### **Physical Characteristics**

The three acre site contains five brick kilns, a combined office/blower house, and a warehouse. The balance of the former waste storage facility is an open field covered with grass and shrubs, and the surrounding area is primarily forested. An Illinois Central railroad track runs through the property parallel to the brick kilns. Several house foundations and an old barn are situated about 300 feet to the east of the railroad. A dirt road runs from the area across the railroad tracks to Dixie Highway. A chain-link fence with a gate at the dirt road parallels the highway and is the only barrier to the site. Other boundaries of the site are unsecured.

#### **Land and Resource Use**

As previously stated, the Brickyard site is an area of low lying grass land with a fair amount of forestation. Land in the area supports minimal agriculture and low density housing.

The site is situated in the Ohio River valley, the bank of which is approximately 0.2 miles northwest of the site. The valley is narrow near the site, but widens upstream. The great alluvial aquifer along the Ohio Valley is a principal natural resource of the region affected by the site. Two distinct alluvial deposits form the aquifer. They are the Fine Grained Alluvium (FGA) and the Coarse Grained Alluvium (CGA) which unconformably overlie the Mississippian bedrock. The FGA mainly consists of silt and clay. Therefore, it is tight. The CGA is directly below the FGA and is made up of sand and gravel. Therefore, it is significantly permeable.

The alluvial deposits in the Ohio Valley range from 0 to 110 feet in thickness with varying degrees of productivity. Wells that encounter the CGA may yield as much as 1,000 gallons of water daily while those completed in the FGA may be negligibly productive. The Mississippian bedrock, consisting of limestone and shale, generally yields little or no water to wells.

Several domestic wells existed in the area and produced from the CGA primarily when the site was initially discovered. Many of these wells have been abandoned over the years due to mechanical problems and/or availability of public water lines. As part of this study, the State surveyed residences in the area and reported that the domestic wells previously sampled for site monitoring purposes were no longer available. Area homes now depend on public water supply.

## **History of Contamination**

The property was used as a brick manufacturing plant between 1950 and late 1976. Shortly after that, Kentucky Liquid Recycling Inc., founded by Mr. Donald Distler, leased the property from the owner for use as a waste recycling and storage facility.

In late 1976, Mr. Distler attended a Kentucky Governor's Conference on the Environment and engaged in a general conversation with an employee of the Kentucky Bureau of Environmental Protection. During the conversation, Mr. Distler indicated that he was planning to build a hazardous waste incinerator in Kentucky and that he was already in business in the area collecting and storing hazardous waste. This led to an investigation of Mr. Distler's activities by the Commonwealth and the discovery of the waste storage facility operated by him at the Brickyard location.

In early 1977, an enforcement action was initiated by the Kentucky Natural Resources and Environmental Protection Cabinet (KNREPC) against Mr. Distler. The Federal Bureau of Investigation, U. S. EPA and KNREPC inspected the site and found a significant number of drums containing waste stored on the property. Subsequently, approximately 30 of the drums were sampled and a restraining order was served on Mr. Distler prohibiting further use of the property for storage or disposal of industrial waste. A follow-up official visit to the property revealed that Mr. Distler did not heed the order immediately.

In August 1978, EPA reported the results of the initial field sampling and indicated that the sampled materials were toxic. KNREPC served an Order to Abate and Alleviate Operations on Mr. Distler in January 1979. This action prompted a partial removal of drummed wastes from the property and prevented further storage activities. Between January 1979 and December 1981, several additional orders were issued to Mr. Distler for further removal of waste from the facility. The orders were ignored. In December 1981, KNREPC requested EPA to initiate an emergency removal action at the property.

In March 1982, EPA removed approximately 2,300 drums of hazardous waste from the property. The drums were found to contain various liquids, sludge and solids which were sampled and described as toxic, corrosive, volatile and/or flammable. Soils contaminated by leaking drums were sampled and removed also. Air monitoring to evaluate air quality and geophysical surveys to explore for buried drums were conducted. The results of these activities indicated no air quality problems, two possible areas of buried drums and potential groundwater contamination due to spills and leaking drums.

Additional investigations were conducted in 1982, to confirm the nature of soil contamination and to delineate the extent of possible groundwater contamination. Results of these investigations were used to support placing the site on the National Priorities List (NPL) in 1983.

## **Basis for Taking Action**

Remedial Investigation (RI) activities aimed at a detailed evaluation of the site for necessary cleanup then followed. The RI report, which was completed in 1985, confirmed soil and groundwater contamination. The contaminants of concern found in the groundwater and/or the soil within the site boundaries were: arsenic, chromium, lead, benzene, bis(2-ethylhexyl)phthalate, 2-butane, 1,1,-dichloroethene, naphthalene, toluene, trans-1,2,dichloroethene, trichloroethene and 1,1,1-trichloroethane.

Based on the RI results, EPA concluded that the contaminants of concern were confined to the site, but that hydrogeologic information suggested that the contaminants were likely to migrate offsite with time. Consequently, a Feasibility Study (FS) was conducted between 1985 and 1986, to determine necessary remedial measures.

## **IV. REMEDIAL ACTION**

### **Remedy Description**

A public meeting was held in April 1986, to discuss the findings of the RI/FS and to explain the proposed remedies for the site. In August 1986, EPA published a Record of Decision (ROD), which reflected the results of the RI/FS and public comments. The ROD specified the following RA activities.

1. Excavation of contaminated soils to background level, removal and off-site disposal of contaminated soil, back-filling with clean soil, re-grading and seeding for new grass.
2. Extraction and on-site treatment of contaminated groundwater to background levels and re-injection into the aquifer.
3. Operations and Maintenance (O & M) of the groundwater treatment system and upkeep of site grounds.

Remedial Design (RD) began in April 1987. It was completed in October 1988. In conjunction with the RD, additional soil and groundwater samples were collected from the site and a soil remediation study was conducted. Based on the results of these activities, EPA and the Commonwealth agreed to modify the cleanup goals stated in the ROD to the following health based Maximum Contaminant Levels (MCLs).

**Table 2: Site Clean-up Goals**

<u>Contaminants</u>	<u>MCL,ppb</u>
arsenic	50
chromium	50
lead	50
2-butanone	170
trans-1,2-dichloroethene	70
1,1,1-trichloroethane	200
trichloroethylene	5
benzene	5
toluene	2000
1,1-dichloroethylene	7

The changes to the remedy were documented properly in an Explanation of Significant Difference (ESD) which was finalized in October 1988. Notice of the ESD was published in a major local newspaper and public comments were invited. No objections to the changes were raised by the public.

### **Remedy Implementation**

Remediation of contaminated soil was accomplished in late 1988, with a series of excavation and sampling events. After each round of excavation, samples from excavation pits and trenches were analyzed to determine current levels of contamination. This process continued until approximately six inches of native soil had been removed and the final laboratory analysis indicated that all contaminants were either at or below the levels established in the ESD. Analyses of samples were performed at the EPA Environmental Services Division laboratory in Athens, Georgia. Soil excavated from the site was trucked to Emelle, Alabama for proper disposal at ChemWaste's facility. Clean soil was brought to the site to backfill all excavation areas. Top soil was spread and seeds were sown to cultivate grass over the disturbed area of the site as necessary. Thus, soil remediation was completed as stated in the ROD and the ESD.

Groundwater remediation construction began in 1989, with the installation of six recovery wells, two injection wells, and a temporary water treatment facility. These were equipped as a pilot wastewater treatment system and utilized to provide groundwater recovery data on the site. The water recovery system was operated and tested for approximately three weeks.

Evaluation of test data from the pilot treatment system was completed in 1990. The results indicated that the aquifer affected by the site consisted of two different stratigraphic units, the Coarse Grained Alluvium (CGA) and the Fine Grained Alluvium (FGA). In addition, most of the contaminants at the site were in the FGA which exhibited low fluid flow rates and was poorly connected to the highly productive CGA. Therefore, it was concluded that wells located in the

CGA similar to the pilot wells, would not clean up the groundwater effectively.

Between 1991 and 1993, several additional field sampling activities and hydrogeologic studies were conducted in order to characterize the FGA further and to obtain data necessary for designing an appropriate set of water extraction wells. All existing data and technical reports on the site were reevaluated. As a result of these efforts, it was determined that clusters of wells installed in phases would be appropriate for the groundwater cleanup.

Final remedy construction resumed at the site in August 1993, when four new recovery wells were installed in the FGA near the only existing FGA well. All five wells were developed, sampled and tested for hydrologic data. The information obtained was used to design the system for groundwater treatment. The system consisted of two carbon adsorption units, filters, meters and flowlines. Installation of the treatment system in September 1994, concluded this phase of remedial construction.

Long Term Remedial Action (LTRA) began at the site in September 1994. Initially, Bechtel/ICF (EPA contractors) provided the field services, including operations and maintenance of the groundwater pump and treat system, periodic sampling of the groundwater recovery wells, and reporting of site activities. Analytical results for the groundwater samples were reported regularly to USEPA. In early 1996, responsibility for the LTRA was assumed by the Commonwealth of Kentucky under a Cooperative Agreement with USEPA. Kentucky continues to lead the operation of the LTRA currently.

### **Summary of Last Five-Year Review**

The first Five-Year Review of the site was conducted in 1998. As part of the review, site inspections were made, ARARs, were reviewed, and sampling as well as laboratory reports were evaluated. The findings of the review were as follows:

1. The clean-up goals established in the ESD were appropriate relative to Federal and State drinking water standards for the contaminants at the site except for lead and toluene. The goal for lead was 50 parts per billion (ppb) versus the current acceptable maximum level of 15 ppb. The goal for toluene was 2000 ppb while the current standard was 1000 ppb.
2. Progress and conditions of the LTRA project were being monitored carefully by regular site inspection and groundwater sampling. No physical inadequacies were observed when the site was inspected for the Five-Year Review. Site visit reports regularly submitted to EPA by the State indicated that equipment breakages or wear and tear occasionally occurred at the site. Snow, rain, and flooding periodically interrupted field activities. However, these problems were resolved as expeditiously as possible.
3. The following Table 3 was presented to summarize the laboratory results obtained from groundwater monitoring since the startup of the LTRA through 1998. COC concentrations presented were the project area average for recovery wells sampled at each period. The Table

also compared the clean-up goals established for the COCs at the site and the current federal drinking water maximum contaminant levels (MCL).

**Table 3: Site Sampling Data (March 1995-April 1998)**

AVERAGE CONCENTRATIONS, PPB

COC	Goal	MCL	Mar 95	Jun 95	Sep 95	Jun 96	Dec 96	Mar 97	Jun 97	Dec 97	Apr 98
Arsenic	50	50	nd	4	11	22	67	76	5	60	179
Chromium	50	100	nd	nd	1	nd	7	nd	nd	10	17
Lead	50	15	nd	9	5	122	29	8	nd	11	20
2-Butanone	170	170	nd	nd	nd	nd	nd	nd	nd	nd	nd
Trans-1,2 dichloroethene	70	100	374	187	306	4	8	1	nd	680	2
1,1,1 trichloroethane	200	200	2	nd	2	nd	4	nd	nd	6	nd
Trichloroethylene	5	5	1	nd	nd	1	18	3	nd	33	18
Benzene	5	5	4	nd	nd	nd	22	nd	nd	6	15
Toluene	2000	1000	2	nd	2	137	nd	101	4	93	183
1,1-dichloroethylene	7	7	188	70	154	nd	2	99	58	25	nd

Based on the information, chromium, 2-butanone, 1,1,1-trichloroethane, and toluene in the area drained by the recovery wells no longer posed human health or environmental concern at the time of the review. Average concentrations for these compounds were much lower than the current MCLs. Generally, all other COCs remained at unacceptable concentration levels. They were fluctuating between non-detect and levels considerably higher than the MCLs.

4. Considering the complexity of the site's geology, USEPA contracted with the United States Geological Survey (USGS) at the start of the LTRA to provide special monitoring services. The services which began in August 1995, included collection of hydrologic data and groundwater sampling. Results obtained by USGS were similar to those discussed above. Furthermore, USGS observed that contaminant levels fluctuated in direct response to seasonal variation in groundwater levels. Low contaminant concentrations were observed during wet periods with rising groundwater levels and high concentrations occurred during dry seasons.

5. In spite of the fluctuation, it was clear that contaminants were being extracted from the groundwater by the clean-up system. However, contaminant extraction rate was low apparently due to low water yield from the FGA in which the recovery wells were placed. The five wells

pumping the groundwater tested at the start of the LTRA for a yield of approximately 29 gallons of water per hour. Subsequently, the yield averaged approximately 3 gallons per hour.

6. In March 1994, USGS sampled six residential wells near the site. The samples were analyzed at the USEPA laboratory in Athens, Georgia, for metals and volatile organic compounds. None of the wells exhibited site-related contamination. In addition, USEPA and Kentucky project managers conducted another sampling of residential wells in the area in May 1998. The samples were analyzed by the Commonwealth and no site-related compounds were reported at unacceptable concentrations.

On the basis of the findings, the 1998 Five-Year Review concluded as follows:

1. Four of the ten COCs at the site were below the clean-up goals. The other COCs remained at unacceptable concentrations. Therefore, the cleanup was progressing and the project was maintaining its goal of protecting human health and the environment.
2. The persistent COCs at the site were being recovered at extremely low rates. The prevailing flow rate for the system was significantly lower than expected which could be a function of limited aquifer capacity and/or transmissivity in addition to possible clogging of the recovery wells by solids in the flow streams.
3. Results of private well sampling conducted in 1994 and 1998 indicated that the site was not adversely impacting private well drinking water supplies in the area. Therefore, migration of contaminants beyond the boundaries of the site did not appear to be an issue.

Pursuant to the conclusions, the five-year review recommended the following:

1. Conduct a special evaluation of the LTRA to determine a more efficient contaminant recovery method.
2. Test, backwash, or re-complete existing wells as necessary.
3. Install and properly complete additional recovery wells.
4. Evaluate applicability of innovative contaminant recovery methods such as horizontal wells and french drains.

## **V. PROGRESS SINCE LAST REVIEW**

Pursuant to the foregoing recommendations, studies were initiated immediately to determine methods of improving the effectiveness and speed of site cleanup. EPA Region IV expanded the scope of work for the existing contract with the USGS to provide a comprehensive evaluation of the cleanup progress from a geologic and hydrologic standpoint. The EPA Office of Research and Development in Las Vegas was also requested to provide technical assistance on the site



with a view to evaluating site performance to date and determining appropriate technologies for enhancing contaminant recovery. The Las Vegas office then contracted with the Idaho National Engineering and Environmental Laboratory (INEEL) to assist on the site. Since then, USGS and INEEL have conducted all technical work related to the site and have produced significant results. The following is a summary of the progress to date.

As stated before, EPA contracted with the USGS at the beginning of this LTRA to monitor and evaluate its progress. Therefore, between 1995 and 1997, the USGS collected and analyzed several rounds of water samples from the site and utilized the information to assess the performance of the LTRA. Four site monitoring wells were selected for strategic sampling in order to study the behavior and characteristics of the COCs under the prevailing geologic conditions at various locations over the study period. Trends in the chemical compositions of site contaminants were examined to determine the factors affecting their subsurface fate and transport mechanism. The study also included a perusal of existing reports on the site and an extensive technical literature review to obtain an understanding of the site and its condition.

The USGS presented the findings of the study to EPA and the State in an unpublished report in 1999. The abstract and conclusions of the study are presented in this report as Exhibit 1 and the findings are summarized as follows.

1. Examination of spatial and temporal trends of VOCs at the site indicates that residual hydrocarbon contaminants are trapped by capillary pressure in the subsurface forming the sources of groundwater contamination.
2. Chlorinated and aromatic hydrocarbon chemicals diffuse from storage and are transported by advection and dispersion from the FGA to the CGA.
3. Bioremediation via anaerobic reductive dechlorination appears to be actively removing the chlorinated solvent at the site.
4. Effectiveness of the dechlorination process is curtailed by the difference in stratigraphy, geochemical environment, and source of recharge between the FGA and CGA. Conditions of the FGA are more suitable for the process than those of the CGA.
5. The potential for enhanced biodegradation of the contaminants especially in the CGA must be investigated further using special monitoring data that are currently unavailable.
6. The diffusion-dominated contaminant transport mechanism in the subsurface could limit the ability of the groundwater extraction wells to remove contaminants from the FGA. Hydraulic gradients generated by pumping generally can be insufficient to remove residual contaminants in tight formations such as the FGA.
7. Effectiveness of the pump and treat system at the site appears to be hindered by the low permeability and poor yield of the FGA.

8. Given the evidence of biodegradation in the FGA, migration of more soluble, less chlorinated degradation products into the CGA, and the superior quality of CGA permeability, extraction wells completed in the CGA would effectively and more rapidly help to clean the site.

INEEL began its activities at the site in 1998. The activities have included a review of the USGS study, further site characterization by installing new wells, groundwater sampling, and soil gas monitoring. In addition, an innovative technology has been designed and deployed at the site by INEEL to address the specific conditions of the site based on USGS study and the results of INEEL's site characterization work. The following is a summary of INEEL's activities.

Initially, the group reviewed existing site reports and evaluated the study recently completed by USGS. As a result of this activity, INEEL concluded, as USGS did, that site contaminants appeared to be subjected to a limited amount of biodegradation, and that additional sampling was necessary to address data gaps related to potential augmentation of the limited biodegradation process. Therefore, new site characterization events were conducted by INEEL and USGS collaboratively, including new well installation, groundwater sampling, and soil gas collection. Information derived from these activities were used to confirm that some contaminant biodegradation processes were in effect at the site which could be enhanced by an appropriately designed technology. Details of this work and its results are in Exhibit 2 of this Five-Year Review report.

Soon after the above work was completed, a private company, North Wind Environmental, Inc., essentially made-up of INEEL's scientists and engineers conducting the studies above, began to address the issues at the site for EPA. In year 2000, North Wind recommended the application of an enhanced bioremediation process at the site. The process was proposed to be a combination of hydraulic fracturing of the contaminated aquifer to improve permeability and the injection of chitin to stimulate sub-surface microbial activity. EPA evaluated the proposal and approved it with State concurrence.

Although field use of hydraulic fracturing to improve tight formation permeability is common, the Distler Brickyard Site became the first location for field application of chitin to enhance bioremediation at a Superfund site. The combined fracturing-chiting injection field test at the site was proposed to the National Science Foundation as an Innovative Technology by North Wind and the pilot project received an award of one hundred thousand dollars (\$100,000). The test was conducted from October 2001 to January 2002. Chitin is a solid polymeric organic material. It consists of shrimp and crab shells and has been shown in laboratory research to be capable of stimulating the growth of indigenous organisms which can degrade contaminants such as found at Distler Brickyard. The material was deployed at the site under pump pressure into the appropriate wells, mixed with sand as a slurry to create fractures in the formation and to prop the fractures.

Based on field sampling data collected before and after the pilot test was conducted, North Wind reported that the technology was successfully applied at the site and that the LTRA would benefit from a full-scale application of the process. North Wind's report on the pilot project is presented

as Exhibit 3 in this document.

In view of the success of the pilot project, EPA and the State supported North Wind's proposal to the NSF for funding to implement the innovative technology at the entire site as a full scale project. In January 2003, North Wind received a grant of four hundred thousand dollars (\$400,000) from the NSF for the project. In April 2003, North Wind initiated the project with the construction phase which primarily included the construction of new wells and the process of formation fracturing through selected site wells. Project construction was completed in May 2003, and the monitoring phase of the project as planned and undertaken by both North Wind and USGS is in progress at this time. The construction phase was reported as successful but no information is available yet to evaluate its effect on the groundwater cleanup. However, the full-scale application of the technology was designed and conducted on the basis of the prototype which produced favorable results. See Exhibit 4. Therefore, the LTRA is expected to be improved significantly with time as a result of this enhanced bioremediation process.

Monitoring activities are scheduled to continue at the site through September 2004. Results of the activities should be available by January 2005. Site conditions will be evaluated then on the basis of the monitoring results and appropriate actions will be determined. Details of the results and progress of the clean-up efforts will be reported in the next Five Year Review which is due in September 2008.

## **VI. FIVE YEAR REVIEW PROCESS**

### **Administrative Components**

USEPA was the Lead Agency responsible for this Five-Year Review. EPA Region 4 and the Commonwealth of Kentucky conducted the review. The primary personnel on the project for EPA Region 4 and Kentucky respectively were Mr. Femi Akindele and Mr. Ken Logsdon.

### **Document and Data Review**

The documents reviewed for this report included the First Five-Year Review for the site, work plans and project reports from USGS, INEEL, and North Wind. Field and laboratory data contained in the reports were analyzed and current Federal and State MCLs were compared with site clean-up goals.

### **Site Inspection**

Kentucky inspected the site periodically during the period reviewed and observed no abnormal conditions other than site flooding during heavy rains. USEPA and Kentucky jointly inspected the site as part of this Review on August 22, 2003, and found no unusual situations or indications of adverse effect on the project.

## **Community Involvement Activities**

In July 2003, USEPA developed a fact sheet which summarized current information about the site. The fact sheet was mailed out to update the public on clean-up activities, to announce that this Five-Year Review would be conducted, and to solicit public participation in the Five-Year Review. On August 6, 2003, the announcement was posted on EPA Region 4 website. In addition, the USEPA Community Involvement Department announced that the Five-Year Review was in progress in a local newspaper (TV Week) on September 7, 2003, and conducted a number of telephone interviews with local residents and public officials. Documents related to these community participation activities are attached as Exhibit 5.

## **VII. TECHNICAL ASSESSMENT**

Question A: Is the remedy functioning as intended by the decision documents?

The LTRA at this site was constructed and operated as required by the Superfund decision documents. The documents established certain clean-up goals some of which the remedial activities at the site have attained as discussed in this and previous Five-Year Review reports. The recent application of an enhanced clean-up technology at the site should speed up the degradation of the remaining site contaminants.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives used at the time of the remedy selection still valid?

At the time the remedy selection was made, cleanup goals established for lead and toluene were 50 ppb and 2000 ppb respectively. The current MCLs for these compounds are 15 ppb and 1000 ppb respectively, which this LTRA should achieve before terminating. In addition, the cleanup goal for arsenic was 50 ppb. EPA revised the MCL for this compound to 10 ppb effective April 24, 2003. This more stringent standard also is expected to be met in due course. Other parameters referred to in this question are believed to remain valid.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

This Review did not discover any other information that could call the protectiveness of the remedy to question.

## **Technical Assessment Summary**

Based on this Five-Year Review, the remedy at the Distler Brickyard Site was designed and implemented as intended by the decision documents. The clean-up activities implemented at the site have met some of the remedial action objectives and/or current MCLs. Performance of the LTRA will continue to be monitored to ensure that the site continues to protect human health and

the environment appropriately.

## **VIII. CONCLUSIONS & OBSERVATIONS**

The conclusions resulting from this Review are:

1. Some, but not all, clean-up goals for the Brickyard Site have been achieved by virtue of the remedy implemented at the site based on the monitoring data evaluated for this Review.
2. The pilot test of the enhanced bioremediation technology recently applied at the site indicated that the technology would expedite degradation of the persistent COCs to acceptable levels. Construction of the full-scale application of the "chitin-fracturing" technology has been completed successfully.
3. Monitoring activities are in progress at this time to ensure that the technology achieves its goal of enhancing the site cleanup.
4. This Review did not discover any issues of significance relative to the performance of site remedy. No conditions of potential adverse effect on the future protectiveness of the remedy were observed.

## **IX. RECOMMENDATIONS AND FOLLOW-UP ACTIONS**

Continue to monitor the site in light of the recent bioremediation enhancement efforts. EPA and the State should ensure that USGS and North Wind are properly funded to continue providing technical assistance at the site until all clean-up goals are met. Current levels of EPA and State oversight of the LTRA should be maintained to ensure that the project is evaluated regularly and its progress documented properly for the next Five-Year Review.

Pursuant to the current Fund-Financed State-Lead Cooperative Agreement for the site, KDEP will continue to be responsible for all site activities and reporting. EPA will continue to provide technical support as necessary.

## **X. PROTECTIVENESS STATEMENT**

The remedy implemented at the Distler Brickyard Site currently protects human health and the environment. Many of the COCs at the site have been reduced to acceptable concentration levels. Enhanced remedial measures have been taken to ensure that the remaining COCs are cleaned up rapidly. There are no technical or physical issues related to the site that are likely to reverse its current level of stability and protectiveness of human health and the environment.

## **XI. NEXT REVIEW**

The next Policy Five-Year Review Report for this site will be prepared no later than September 2008.

## **Exhibit 1**

### **USGS 1999 Study Report--Abstract and Conclusions**

INVESTIGATION OF TRENDS IN VOLATILE ORGANIC CHEMICALS IN GROUND WATER AT THE DISTLER BRICKYARD SUPERFUND SITE, HARDIN COUNTY, KENTUCKY, 1995-1997

ABSTRACT

Temporal and spatial trends in the concentrations of volatile organic chemicals detected in ground-water samples in 1995-97 at the Distler Brickyard Superfund Site, Kentucky, were examined for evidence of contaminant mass reduction by natural attenuation and pumping of ground-water extraction wells. The results of ground-water sample analyses, summary statistics for VOCs detected in four monitoring wells completed at various depths in the aquifer system, and possible factors affecting subsurface transport and fate of identified ground-water contaminants are discussed. This information will be used to assist federal and state regulators conducting an evaluation of ground-water quality at the site, the potential for degradation of nearby public-water supplies, and the need for additional remedial actions.

The aquifer system is composed of layered and interbedded alluvial and glaciofluvial sediments and is divided into an upper, fine-grained alluvial aquifer (FGA), and a lower, coarse-grained alluvial aquifer (CGA). Trends in the distribution and apparent concentrations of chlorinated aliphatic and aromatic hydrocarbons provide evidence that anaerobic reductive dechlorination of chlorinated hydrocarbons is occurring in the upper aquifer zone (FGA), and aerobic biodegradation of fuel hydrocarbons is occurring in the lower aquifer zone (CGA). Although specific geochemical data needed to assess oxidation-reduction potentials in the aquifer system is presently unavailable, evidence is presented that the reductive dechlorination process is enhanced in the FGA by the presence of fuel hydrocarbons and other organic material. In contrast, reductive dechlorination seems to be inactive or inhibited in the CGA, possibly because of the occasional influx of oxygenated recharge from a hydraulic connection with the Ohio River, a lack of organic matter, or the absence of inorganic minerals needed as electron donors and acceptors. Because of the presence of residual hydrocarbon contaminants, and relatively low overall permeability and transmissivity, ground-water extraction wells completed in the FGA may not be effective at reducing contaminant masses in the upper aquifer zone. Given evidence that intrinsic bioremediation of chlorinated hydrocarbons is reducing the mass of contaminants in the upper aquifer and generating more-soluble, less-chlorinated degradation products, extraction wells completed in the CGA may be effectively used to reduce the aqueous contaminant concentrations and minimize the potential for off-site migration.



## SUMMARY AND CONCLUSIONS

Evidence provided in this report by the examination of spatial and temporal trends of volatile organic indicates that residual hydrocarbon contaminants trapped by capillary pressure in alluvial sediments are the sources of aqueous contaminants detected in ground water at the Distler Brickyard Site in 1995-97.

Chlorinated and aromatic hydrocarbon chemicals diffuse from storage and are transported by ground-water advection and dispersion from the upper fine-grained alluvial aquifer to the deeper coarse-grained alluvial aquifer. Chlorinated aliphatic hydrocarbons (CAHs) and monocyclic aromatic hydrocarbons (MAHs) were the principal VOCs detected in ground-water samples collected at the Site during 1995-97. Of the CAHs detected, concentrations exceeded MCLs for TCE in 57.1 percent of all samples, for c1,2-DCE in 45.8 percent of samples, for 1,2-DCA in 44.7 percent of samples, and for 1,1,2-TCA in 14 percent of samples. Of the MAHs detected, concentrations exceeded MCLs for ethylbenzene in 38.5 percent of all samples, for toluene in 22.2 percent of samples, and for xylene in 18.2 percent of samples.

Intrinsic bioremediation by anaerobic reductive dechlorination seems to be actively reducing the mass of chlorinated solvents in ground water at the Site. Evidence of this is provided by: (1) trends in concentrations of chlorinated aliphatic hydrocarbons that demonstrate the sequential formation of solvent degradation products along the reaction pathway TCA—1,1-DCE—1,1-DCA—CA, or along the reaction pathway TCE—1,2-DCE—1,2-DCA; (2) the absence of PCE/TCE and a reduction in TCA mass (concentration) over time in the FGA at well GW-11; (3) widespread distribution of the intermediate solvent degradation products c1,2-DCE, 1,1-DCA in both the FGA and CGA; and (4) appearance and general increase in mass over time of the advanced degradation product chloroethane in the FGA. The principal anaerobic degradation product of the solvent TCE, c1,2-DCE was detected in all four wells at concentrations approximately one order of magnitude greater than those for secondary anaerobic degradation products t1,2-DCE, and 1,1-DCE. Similarly, 1,1-DCA, the principal degradation product of TCA under anaerobic conditions, was present in all four wells at concentrations approximately one order of magnitude greater than 1,1-DCE, a secondary degradation product generated by abiotic degradation processes.

The effectiveness of reductive dechlorination as a natural attenuation process is complicated by stratigraphic variations and apparent differences in geochemical environment, and sources of recharge, between the FGA and CGA. Although geochemical data are not presently available to assess oxidation-reduction potentials in the aquifer zones, the distribution of CAH and MAH contaminants indicates that reductive dechlorination is enhanced in the FGA, and inhibited in the CGA. The differences in the distribution and concentrations of CAHs, and the apparent rate or efficiency of the reductive dechlorination process in the two aquifer zones, may be related to differences in dissolved oxygen concentrations. Oxygenated water may be contributed to the CGA by a hydraulic connection between the aquifer zone and the nearby Ohio River, and mixing of this recharge with ground water may be sufficient to inhibit anaerobic reductive dechlorination. This conclusion is supported by the observation that fuel hydrocarbons such as ethylbenzene, toluene, and xylene, which biodegrade under aerobic conditions and persist in the anaerobic FGA, were absent in ground water samples collected from the CGA. Further investigation of the difference in geochemical conditions in the FGA and CGA is needed in order to conclusively identify and assess the natural attenuation processes in each aquifer zone.

Common features of attenuating contaminant plumes are a decline in the dissolved contaminant mass as a function of time and with increasing distance from the source (Wiedemeier and others, 1999). Although MAHs and some CAHs exhibit an overall decline in concentration over time, there is considerable short-term (month-to-month) and long-term variation in concentrations for these contaminants. Reductive dechlorination acts both as a natural attenuation process and as a generator (source) of sequentially less-chlorinated hydrocarbon contaminants. Chlorinated compounds will continue to be generated in the aquifer until the source material is completely degraded. Biodegradation rates generally decrease as the chlorine content of the degradation products is reduced. Many of the degradation products formed by reductive dechlorination are more soluble and less reactive with aquifer sediments. Therefore, the degradation products have a generally higher potential to be transported off site and to contaminate a larger portion of the aquifer. The potential for biodegradation processes to be effective in reducing contaminant masses in the CGA must be investigated because the sources of contamination are present in the aquifer and biotransformation of some CAHs may produce degradation products that are more persistent and of a

greater health threat than the parent compounds. An example is the transformation of TCE to 1,2-DCE and finally to vinyl chloride, a known human carcinogen. It appears that geochemical conditions in the CGA do not favor reductive dechlorination of CAHs migrating from the FGA. However, if geochemical conditions in the CGA are variable or change off-site, the CAHs present in the CGA will provide source material for the potential development of more soluble, more toxic degradation products in the lower aquifer zone.

The presence of residual contaminants and diffusion-dominated contaminant transport in the aquifer system limit the ability of the ground-water extraction wells in the FGA to effectively reduce the mass of hydrocarbon contaminants in the aquifer system. Hydraulic gradients generated by pumping are generally not sufficient to remove residual hydrocarbon contaminants in the FGA, and the development of a suitable contaminant capture zone seems to be hindered by the low overall permeability and poor yield of the upper aquifer zone. During much of the latter half of 1995 and early 1996, the ground-water extraction wells at the Distler Site were not operational because of vandalism and weather-related equipment breakdown. Samples collected from November 1995-June 1996 essentially represent the quality of ground water under ambient (non-pumping) conditions. After pumping was re-initiated in June 1996, samples collected from the wells essentially represent the quality of ground water under conditions that include the hydraulic stresses induced by the FGA extraction wells. The concentrations of CAH and BTEX compounds detected in ground-water samples collected after this date did not exhibit any trends that indicate that contaminant masses are being reduced and dissolved concentrations are being lowered by pumping. In fact, the concentrations of many contaminants, such as 1,1,1- TCA, c1,2-DCE, 1,2-DCA, toluene, xylene, and others appear to have been in decline in the FGA before continuous pumping began.

Given the evidence for biodegradation in the FGA and downgradient migration of contaminants into the CGA, ground-water extraction efforts may be more effective if employed to remove dissolved contaminants from the CGA. The greater permeability of the CGA sediments would provide for more rapid cleansing of the deeper aquifer zone by the hydraulic gradients and advection process produced by ground-water extraction. Moreover, a capture zone produced by extraction wells completed in the CGA may help minimize off-site contaminant migration.

Given evidence that intrinsic bioremediation of chlorinated hydrocarbons is reducing the mass of contaminants in the upper aquifer and generating more-soluble, less-chlorinated degradation products, extraction wells completed in the CGA may be effectively used to reduce the aqueous contaminant concentrations and minimize the potential for off-site migration.

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Roy F. Weston Incorporated, 1991. Final report, site assessment, Distler Brickyard, West Point, Kentucky. Unpublished technical report on file at the United States Environmental Protection Agency, Atlanta Georgia.

## **Exhibit 2**

### **INEEL'S Summary of groundwater and Soil Gas Data Collected June-August 2000**

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Wiedemeier, T.H., Rifai, H.S., Newell, C.J., and Wilson, J.T., 1999. Natural attenuation of fuels and chlorinated solvents in the subsurface. John Wiley and Sons, Inc., New York, New York, 617p.

# Summary of Groundwater and Soil Gas Data Collected June-August, 2000 Distler Brickyard Superfund Site, Kentucky Prepared 28 September, 2000

This report provides a description of the data collection activities conducted at the Distler Brickyard Site during July-August, 2000, and a summary of the results obtained from these activities in preparation for the project team meeting scheduled for October 11, 2000. Figures and tables are presented in Appendices A and B.

## 1. GOALS FOR DATA COLLECTION ACTIVITIES

Groundwater sampling conducted in October 1999 led to the hypothesis that natural attenuation via anaerobic reductive dechlorination (ARD) of chlorinated ethenes and ethanes was occurring in the Fine Grained Alluvium (FGA) at the Distler Brickyard Site. However, in order to confirm this hypothesis, additional data were needed. Data gaps were developed to identify the specific data needed to evaluate the above hypothesis. These data gaps are as follows:

- **Data Gap 1: Effect of seasonal recharge on contaminant concentrations.** Previous investigations indicated that the contaminant concentrations fluctuate seasonally (USGS in preparation). The October 1999 sampling event was conducted following an extremely dry summer season. The effect of renewed recharge through the FGA could result in a remobilization of contaminants and cause concentrations to rise. Changing recharge could also result in a shift in the local groundwater flow direction. This information will be very important to the evaluation of the extent of source degradation, which will in turn affect the selection of the appropriate remedial remedy.
- **Data Gap 2: FGA conditions.** The geochemical conditions in the FGA were previously evaluated based on data from a single monitoring location (GW-11). In order to determine the extent of FGA contamination, to define the extent of the dechlorination zone, and to evaluate the extent of source degradation, more monitoring in the FGA is necessary. Again, this information has important implications for assessment of source degradation and subsequent remedial actions.
- **Data Gap 3: Conditions along the GW-11 → MW-3 flowpath.** The contaminant distributions and redox conditions indicate that the flowpath from the presumed source area in the FGA at GW-11 is northerly (toward MW-3 and UDBP-4) rather than to the northwest (toward MW-2) as previous studies indicated. This flowpath may be influenced by the topography of the bedrock surface in this area. It also may be affected by seasonal fluctuations in recharge from infiltration of precipitation through the FGA and influx to the CGA from the Ohio River (USGS, in preparation). Additional monitoring locations along this flowpath are necessary in order to define the eastern boundary of the plume as it migrates towards MW-3 and UDBP-4.
- **Data Gap 4: The extent of aerobic degradation in the Coarse Grained Aquifer (CGA).** In order to determine the extent of aerobic degradation of ARD reaction products in the CGA and off-site contaminant migration, monitoring locations north and west of MW-3 and UDBP-4 are necessary. The concentrations of ARD degradation and mineralization products (dichloroethenes [DCEs], dichloroethanes [DCAs], vinyl chloride [VC], chloroethane [CA], ethene, ethane, and carbon dioxide) will be used to determine the fate of contamination in the CGA.

## **2. FIELD ACTIVITIES**

The field activities conducted at the site during June-August 2000 included monitoring well installation, groundwater sampling, and passive soil vapor monitoring using Gore-Sorbers®. Three new monitoring wells were installed during a two-week period in June. Groundwater sampling was conducted July 10-21. Passive soil vapor monitoring was performed from August 3-21.

### **2.1 Monitoring Well Installation**

Three new monitoring wells were installed at the site in June 2000 (Figure 1). B-1, located south of the warehouse, was installed to a depth of 57 ft. A saturated sand was encountered at approximately 47 ft bgs. Small amounts of gravel were present at the bottom of the borehole, possibly indicating the presence of the CGA in this location. This well produced sufficient groundwater for sampling.

Well C-1 is located west of GW-11 (Figure 1). It was installed to a depth of 53 ft. The same saturated sand was encountered as at B-1. The CGA does not appear to be present at this location. Sufficient groundwater was produced from this well for it to be sampled.

Well B-2 is located east of the kilns (Figure 1). This well was drilled to a depth of 57 ft. No sand or gravel was encountered. The CGA does not appear to be present at this location. The 15-ft screen is located in a silty-fine sandy clay which yielded sufficient groundwater for sampling.

### **2.2 Groundwater Sampling**

Groundwater samples were collected from fourteen existing wells and three newly constructed wells at the Site between July 12 and July 21, 2000. In general, field conditions were good for sampling. The weather was sunny, hot, and humid during much of the month. However, major thunderstorm events occurred in the area over several successive weeks in June and July, generating significant rainfall prior to and during the sampling period. As a consequence, groundwater levels were relatively high in the FGA wells compared to those encountered during the October 1999 sampling effort. In the CGA wells, groundwater levels appeared to be about normal for the season. Despite the recent precipitation, the area is still considered to be in moderate-severe drought, mostly due to residual effects of the 1999 drought.

#### **2.2.1 Sampling of Wells**

Despite relatively high ground-water levels, most wells at the Site remain difficult to sample. A summary of the wells sampled, sampling method, and problems encountered is presented in Table 1.

High turbidity and suspended solids are problematic in most of the FGA wells and in many CGA wells completed with 4-inch diameter steel casing (these wells have caps that do not seal). Overall, well yields are generally low, recharge rates are slow, and excessive drawdown during purging and sampling is difficult to control even at withdrawal rates of less than 1 gallon per minute (gpm). The difficulty in sampling caused by these field conditions was exacerbated by the relatively large quantity of water required to complete the full list of sampling constituents—approximately 3 gallons per well. In all but two wells, this volume of water exceeded the water available in storage in each well prior to purging.

Where pumping could be sustained at 0.5-1.0 gpm without drawing the water level down into the well screen, a Grundfos submersible pump was used to collect all samples. Wells sampled in this manner included: B-2 (newly constructed), MW-1, UDBP-4, UDBP-5, UDBP-6, UDBP-7, and UDBP-8.



### **3. RESULTS**

#### **3.1 Water Levels**

As stated in Data Gap 1, it was necessary to understand the influence of seasonal variations (including changes in precipitation and river stage) on concentrations and degradation of chlorinated ethenes and ethanes. It was hypothesized that an increase in precipitation and subsequent infiltration through the FGA may mobilize residual contaminants, resulting in increased concentrations in groundwater. Also, previous investigations have established a hydraulic connection between the CGA and the Ohio River (USGS, in prep). It was hypothesized that the stage of the Ohio River may affect the local gradient and flow direction at the Distler Brickyard Site. For these reasons, water levels were monitored during the July 2000 groundwater sampling event and were compared to those collected during the October 1999 event to determine if any changes were observed.

Data indicate that the water levels in the CGA were approximately 2.5 feet higher in July 2000 than in October 1999. Well PZ-4, which is screened across both the FGA and CGA had a water level approximately 1.1 ft higher in July 2000. Water levels in the FGA appear to be slightly higher than in October 1999 (< 1 ft). It is assumed that increased precipitation during the spring months resulted in increased infiltration through the FGA.

#### **3.2 Redox Conditions**

Complete ARD of chlorinated ethenes and ethanes requires the absence of competing electron acceptors (oxygen, nitrate, iron (III), and sulfate) in order to be energetically favorable. The results of October 1999 groundwater sampling indicated sulfate-reducing to methanogenic conditions in the FGA in the GW-11 area and iron-reducing conditions extending into the CGA to UDBP-7 and UDBP-8. This suggested that conditions in the FGA around GW-11 were favorable for complete degradation of TCE and 1,1,1-TCA (Martin et al., 2000).

Redox data (dissolved oxygen, nitrate, iron (II), sulfate, and methane) were collected during the July 2000 groundwater sampling event in order to determine redox conditions in the FGA using additional FGA monitoring locations (Data Gap 2) (Table 3). Results indicate a mildly reducing zone (iron-reducing) in the FGA extending into the CGA to include UDBP-7 and UDBP-8. The remainder of the CGA was aerobic with dissolved oxygen concentrations between 2 and 7 mg/L. Sulfate concentrations were relatively high throughout the site (50-90 mg/L). Methane was present at relatively low concentrations (10-60 µg/L) within the FGA (Table 3; Figure 2). These data suggest that redox conditions within the FGA in GW-11 area in July 2000 were slightly less reducing than in October 1999.

#### **3.3 Contaminant Concentrations**

The distribution and concentration of primary contaminants PCE, TCE, and 1,1,1-TCA are of particular importance to the selection of the appropriate remedy for this site. October 1999 groundwater data indicated the presence of TCE in the CGA at concentrations up to 11 µg/L, approximately twice the Maximum Contaminant Level (MCL = 5 µg/L). 1,1,1-TCA was present at concentrations up to 10 µg/L (MCL = 200 µg/L) and PCE was not detected (Martin et al., 2000). In order to determine the extent of FGA contamination (Data Gap 2) and if concentrations of PCE, TCE, and 1,1,1-TCA were affected by seasonal fluctuations in recharge (Data Gap 1), a sampling program including both passive soil vapor monitoring (Gore-Sorbers®) and groundwater sampling was used.

sample. For this reason, the use of these samplers can provide qualitative information on the presence of VOCs and SVOCs in low permeability or unsaturated units, like the FGA at the Distler Brickyard site.

Gore-Sorbers® were deployed in 15 wells (Table 2). The samplers were hung above the water level in each well (if water was present) and the well was sealed at the surface. The samplers were left in the wells for 18 days. Following the equilibration period, samplers were removed and returned to the Gore Laboratory for analysis.

Gore-Sorbers® were chosen to provide qualitative results that give an indication of the presence or absence of remaining FGA contamination. The data are reported by the Gore Laboratory as mass ( $\mu\text{g}$ ) of TCE (for example) per sorber. Equivalent soil gas concentrations cannot be calculated due to the varying volumes of air in each well, thus groundwater concentrations also cannot be calculated. For these reasons, the Gore-Sorbers® were used to detect the presence or absence of contaminants as an indicator of remaining FGA source material. The strength and resultant threat to groundwater posed by a source cannot be determined by this activity.

## **4. DISCUSSION**

Results are discussed in the context of the data gaps described in Section 1.

### **4.1 Data Gap 1 – Effect of seasonal recharge.**

Assessing the seasonal fluctuation in contaminant concentrations is very important to the selection of the appropriate remedy for this site. By comparing water level measurements and contaminant concentrations from October 1999 to July-August 2000, the magnitude of this effect can be determined. Results indicate that water levels throughout the site increased from October to July-August 2000. TCE, cis-1,2-DCE, and 1,1-DCA concentrations also increased throughout the site during this period of time. These results probably indicate that contaminant concentrations fluctuate seasonally and are consistent with a conceptual model in which an increase in recharge in the spring months results in a remobilization of contaminants in the FGA and an increased flux to the CGA.

The seasonal fluctuations in recharge also affected the redox conditions at the site. In general, conditions in July-August 2000 (wet period) were less reducing than in October 1999 (dry period). This indicates that increased recharge at the site results in less reducing conditions, most likely due to the infiltration of oxygenated surface water through the FGA.

Both of these factors indicate that the rate of anaerobic reductive dechlorination of chlorinated ethenes and ethanes will vary seasonally. During dry periods, water levels drop and conditions become more reducing. Contamination remaining in the groundwater is rapidly degraded. During relatively wet periods, increased infiltration results in less reducing conditions. At the same time, rising water levels result in a remobilization of residual FGA contamination. The increased contaminant concentrations and less reducing conditions result in less biodegradation and an increased flux of contaminants to the CGA. The magnitude of this effect will need to be determined through additional sampling timed to changes in seasonal recharge.

### **4.2 Data Gap 2 - FGA conditions**

This data gap contained three components: 1. To determine the extent of FGA contamination, 2. To define the extent of the dechlorination zone, and 3. To evaluate the extent of source degradation. Groundwater and Gore-Sorber® data were used to evaluate the extent of FGA contamination. Results indicate the presence of remaining source contamination in the form of TCE in the GW-11/RW-11 area (TCE and cis-1,2-DCE concentrations equivalent to 700 µg/L TCE at RW-11). Results also indicate the presence of another potential source area in the eastern portion of the site at GW-4 and UDBW-2. The presence of ethene in the GW-11/RW-11 area indicates an active dechlorination zone in this area. This biodegradation is insufficient to prevent the migration of TCE and cis-1,2-DCE to the CGA at concentrations above MCLs (TCE and cis-1,2-DCE concentrations equivalent to 140 µg/L TCE at C-1, UDBP-7, and UDBP-8). The rates of these transformation reactions are likely affected by the changing redox conditions as described above. The presence of cis-1,2-DCE in the UDBW-2/GW-4 area indicates that biodegradation is probably occurring in that area. However, CA and/or VC were not detected, suggesting that dechlorination is not proceeding to completion. The fate of contaminants in this area is not known at this time.

### **4.3 Data Gap 3 – Conditions along GW-11 → MW-3**

October 1999 data indicated that transport of contaminants from the GW-11 source area appeared to be in the direction of MW-3, rather than toward MW-2 as previously proposed (Martin et al., 2000).

## 5. CONCLUSIONS

Results to date generally support the hypothesis that natural attenuation via anaerobic reductive dechlorination of chlorinated ethenes/anes is taking place in the FGA. These results were used to develop the following specific conclusions with regard to geochemical conditions and contaminant fate and transport at the Distler Brickyard Site.

- Two potential source areas exist at the site: 1) GW-11/RW-11 area and 2) GW-3/UDBW-2 area. At RW-11 the equivalent TCE concentration of TCE + cis-1,2-DCE is approximately 700 µg/L (Table 6). While the complete dechlorination pathway of TCE to ethene occurs in the GW-11/RW-11 area, the biodegradation rate is insufficient to prevent migration of TCE to the CGA. TCE migrates to the CGA at concentrations as high as 19 µg/L. The equivalent TCE concentration of TCE + cis-1,2-DCE is as high as 140 µg/L in the CGA (Table 6). The ARD reactions could be limited by a lack of electron donor in the GW-11/RW-11 area. The presence of cis-1,2-DCE in the GW-3/UDBW-2 area indicates that dechlorination occurs in this area. However, due to the lack of adequate data in this area of the site, the fate of contaminants from the GW-3/UDBW-2 area is not known at this time. It is also not possible to evaluate the relative strength of this source in order to predict whether or not it will pose a long-term threat to groundwater.
- Redox conditions in the FGA and in the CGA at UDBP-7 and UDBP-8 are iron-reducing. The remainder of the CGA is aerobic.
- An active dechlorination zone exists in the GW-11/RW-11 area as indicated by both October 1999 and July-August 2000 data.
- Seasonal fluctuations in recharge affect redox conditions, contaminant concentrations, anaerobic reductive dechlorination reactions, and the local groundwater flow directions.

## 6. REMAINING DATA GAPS

The following items represent remaining data gaps for the site. These data gaps need to be addressed prior to the implementation of a final remedy.

- **GW-3/UDBW-3 Source area.** The relative strength of this potential source area needs to be assessed in order to determine the potential threat to groundwater. Also, the transport pathways from this source into the aquifer need to be determined in order to evaluate what action, if any, is necessary in this area.
- **Magnitude and timing of recharge fluctuations.** The magnitude and timing of fluctuations in recharge are necessary in order to determine the highest contaminant concentration that can be produced from the GW-11/RW-11 source area. This has important implications for the selection of a natural attenuation remedy.
- **Local gradient and groundwater flowpaths.** A large gap in the conceptual model for this site is an understanding of the basic transport flowpaths within and from the FGA, and how these flowpaths are affected by seasonal recharge fluctuations. Part of this data gap is understanding the fate and transport of contaminants from the GW-3/UDBW-2 source area. Addressing this issue is key to the implementation of any remedy at this site.

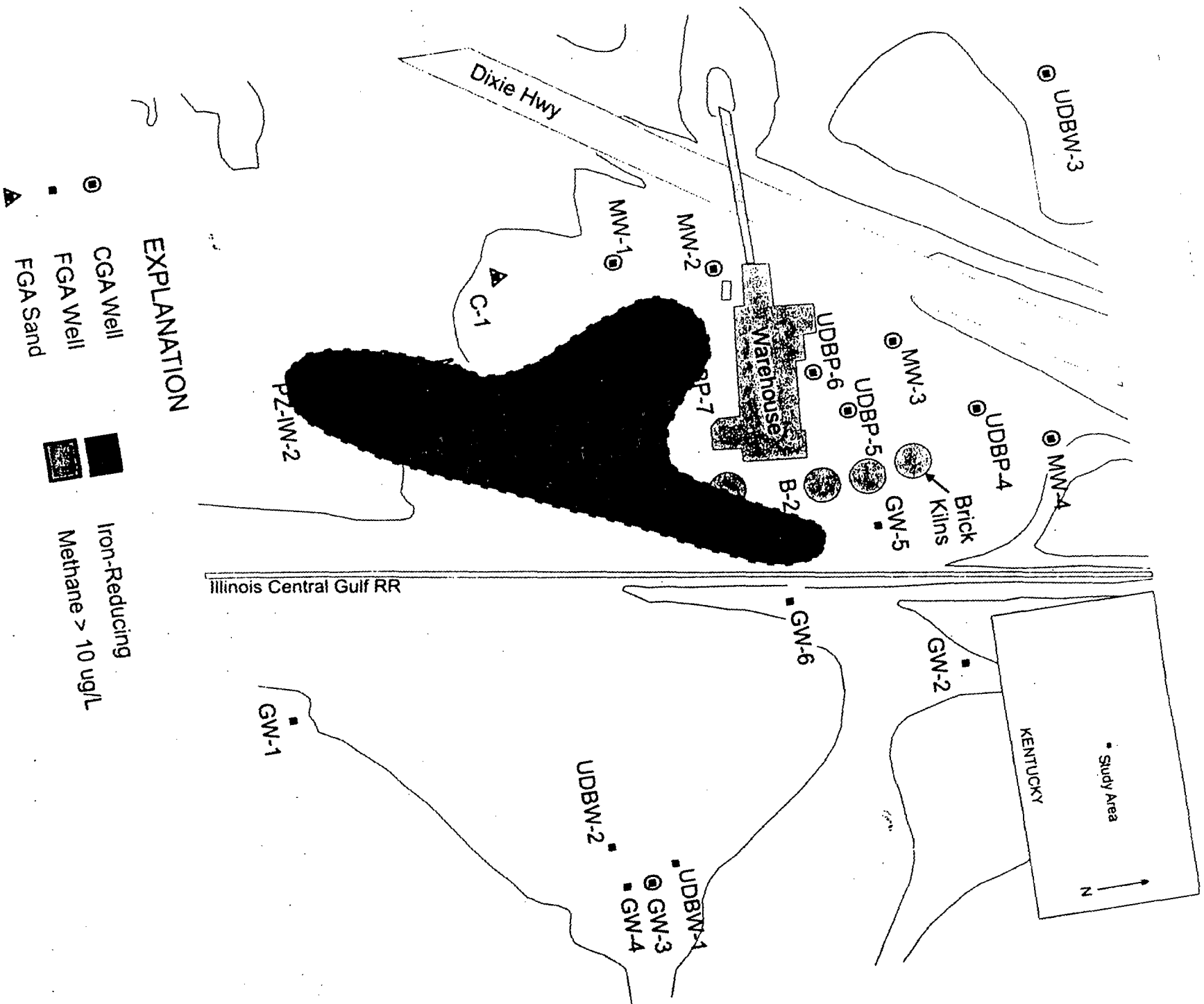
## 7. POTENTIAL REMEDIAL RESPONSE ACTIONS

Potential remedial responses include a monitored natural attenuation program either with or without additional action targeted at the source area(s).

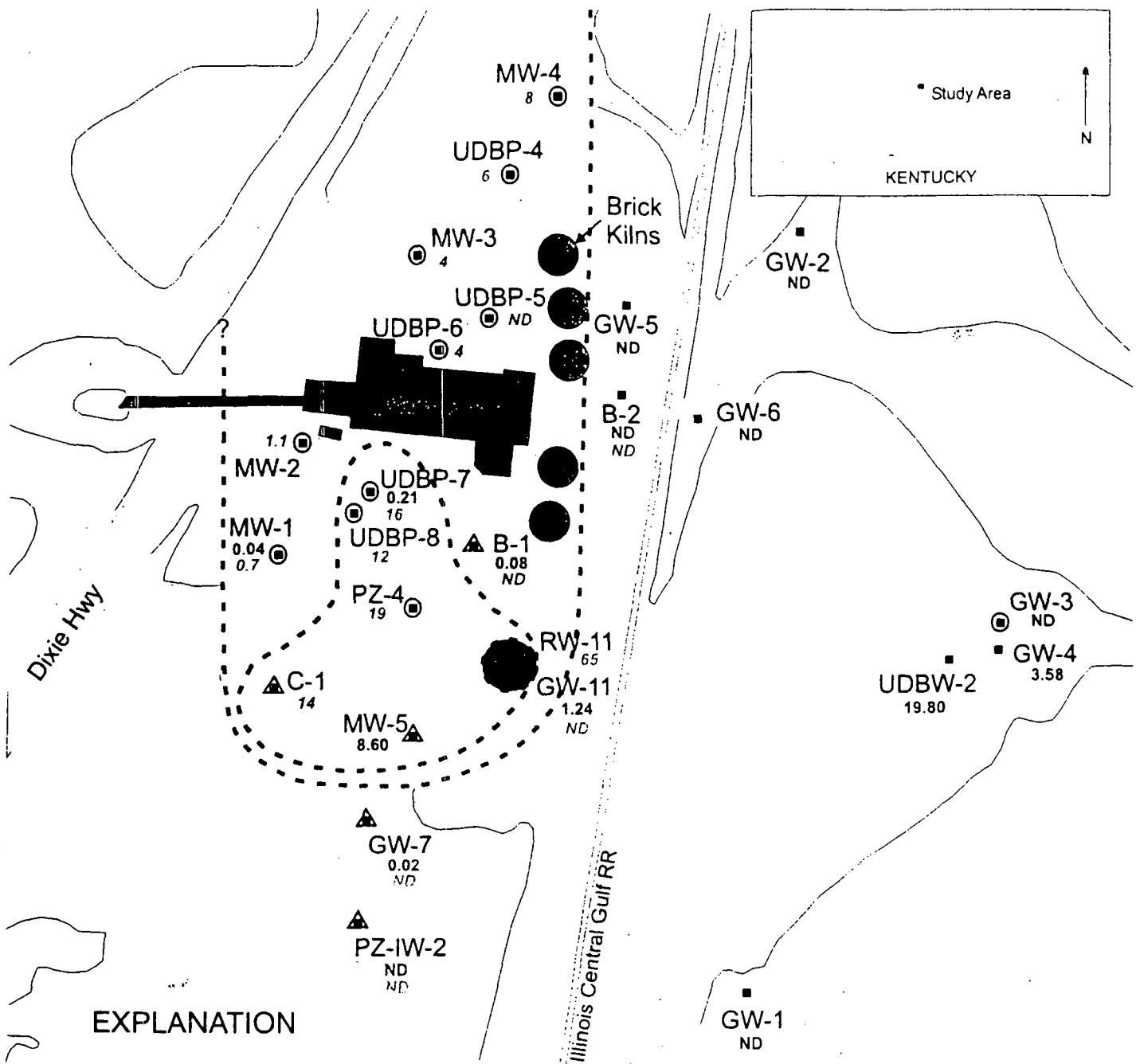
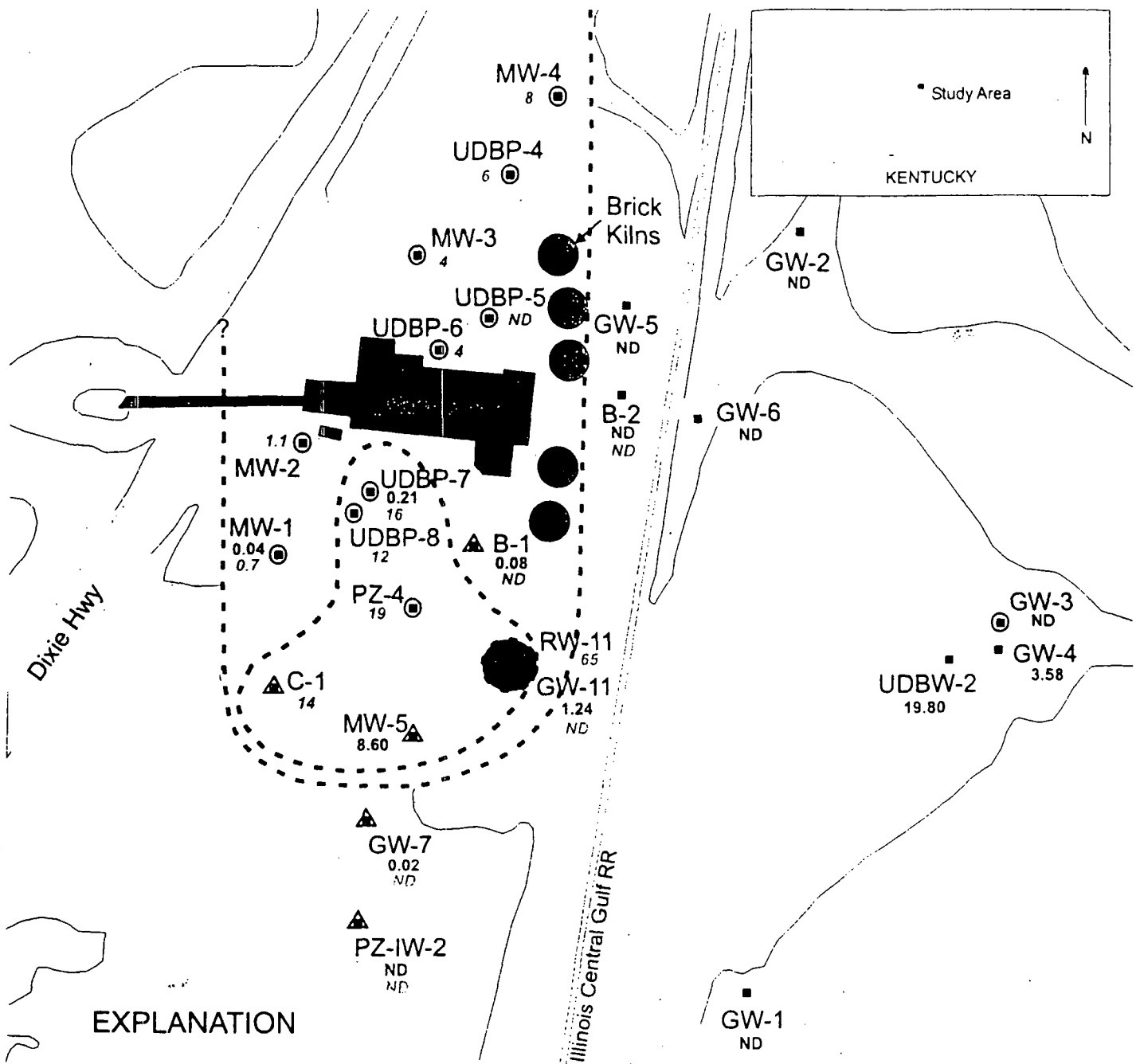
- **Monitored natural attenuation (MNA).** Natural attenuation via dispersion is used in the CGA to address current downgradient contamination.
- **Monitored natural attenuation (MNA) with targeted source action.** MNA can be used in the CGA as described above, however, in these scenarios active remedies are targeted at the FGA source area(s). Active approaches to source area remediation might include:
  - **FGA Source Removal.** Remaining source contamination in the FGA can be remediated through removal of contaminated aquifer material.
  - **Low Cost/Long-Term Remedy.** A low-cost and long-term remedy designed for low permeability materials can be used in the FGA to address remaining source contamination. The ideal technology would be in situ (no groundwater extraction) and would require minimal maintenance once installed.

## **Appendix A**

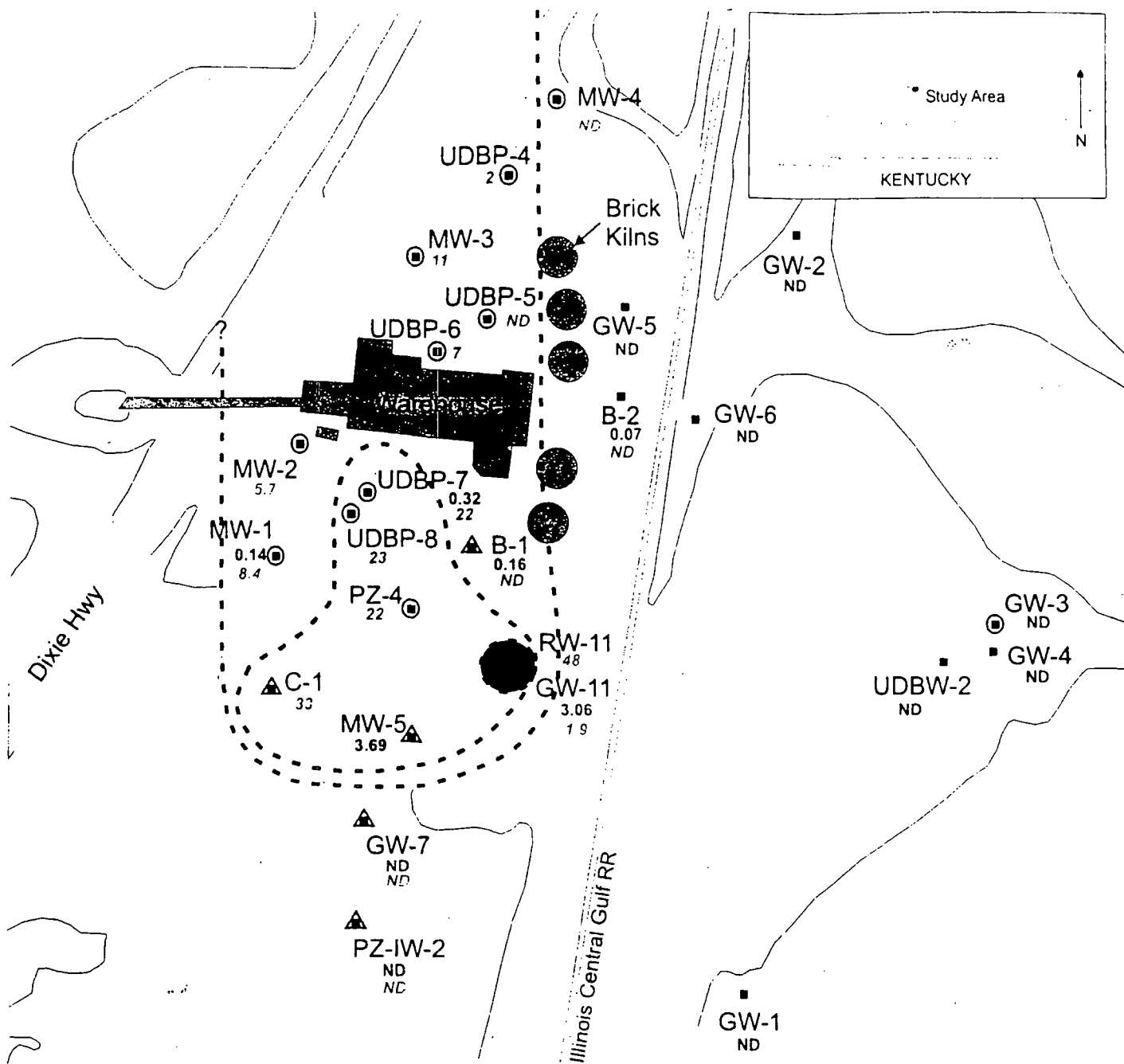
### **July-August 2000 Data Summary Figures**





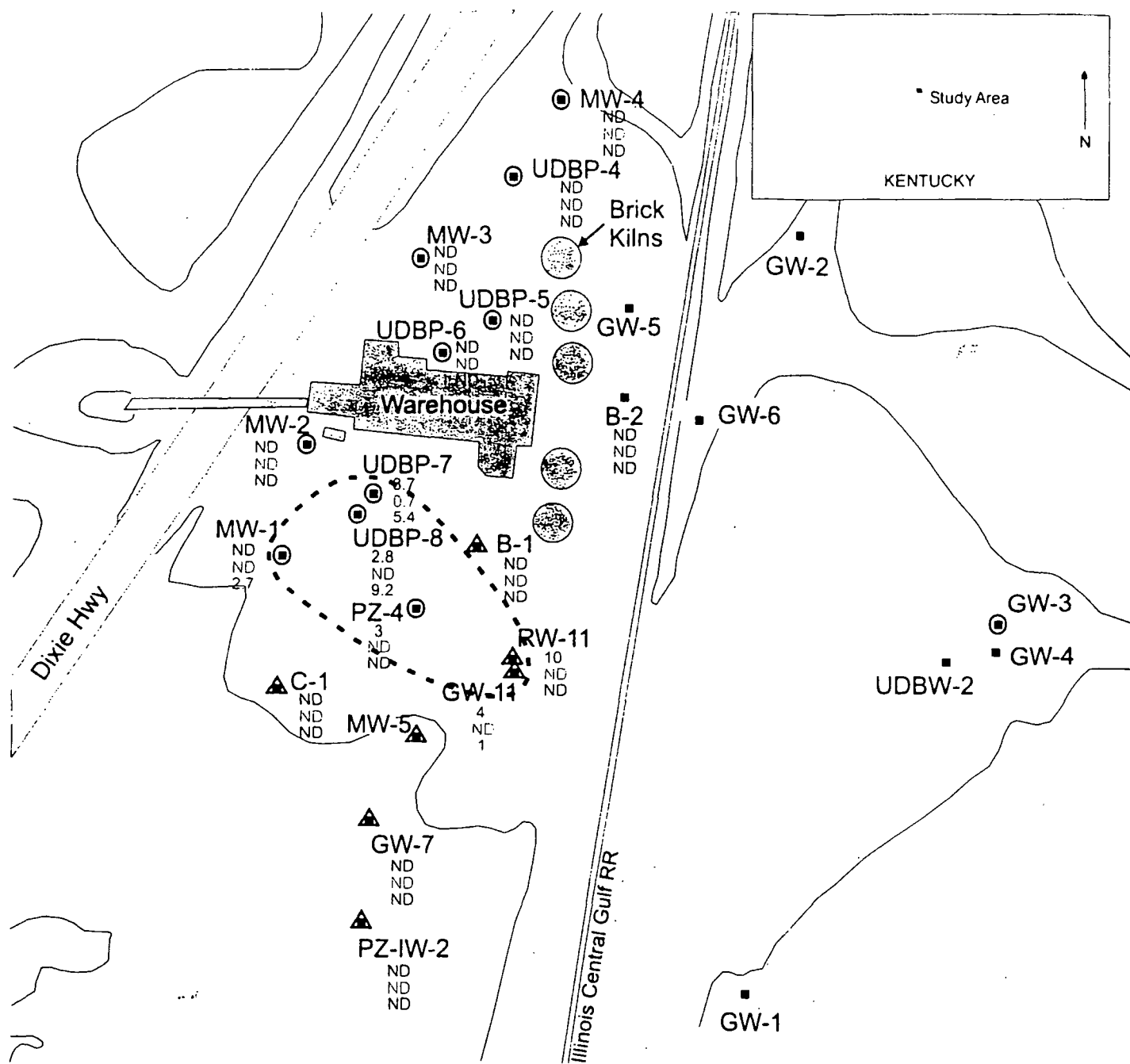






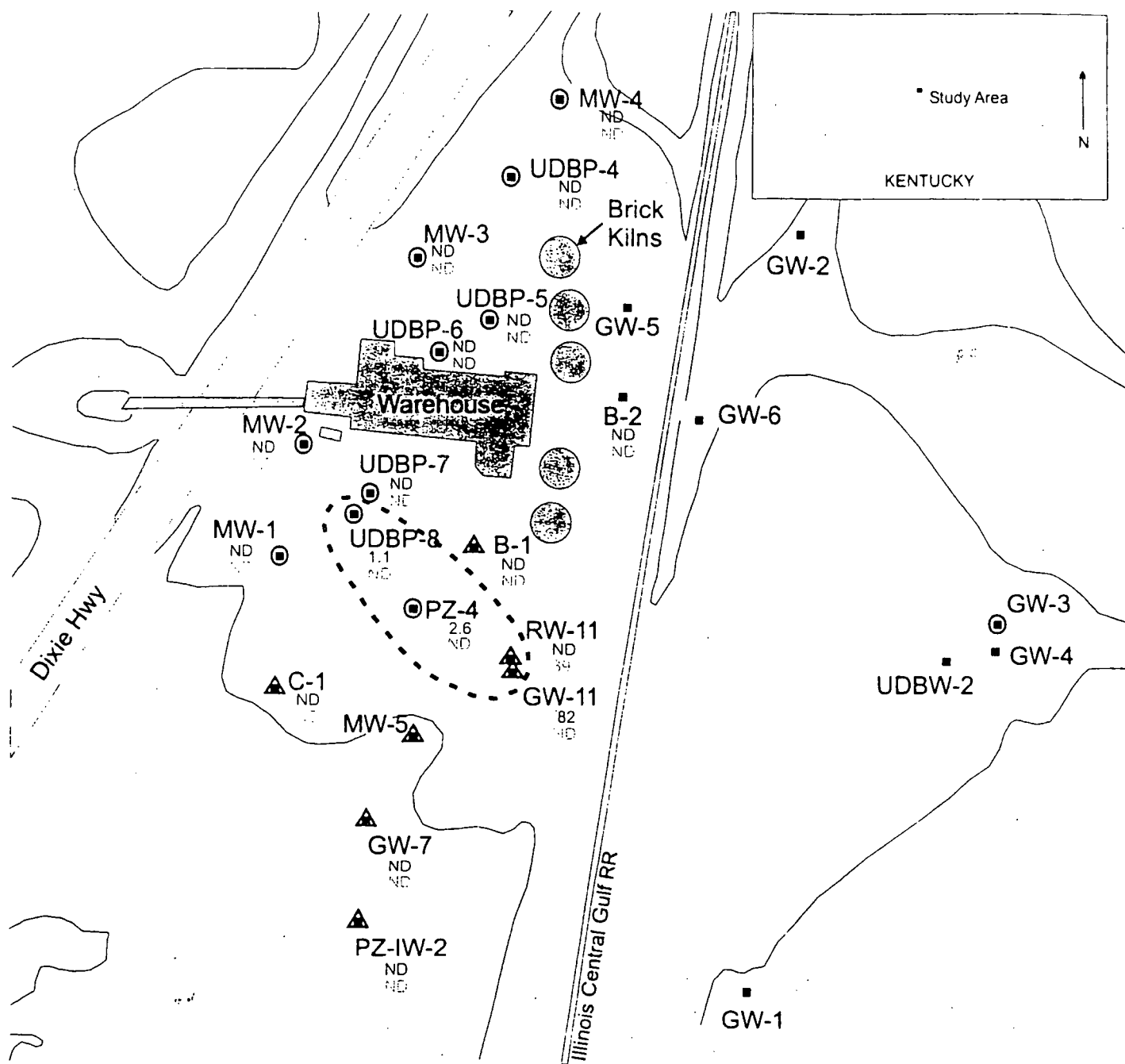
## EXPLANATION

⊙	CGA Well	10	1,1-DCA in Soil Gas (ug per sorber)
▪	FGA Well	10	1,1-DCA in Groundwater (ug/L)
▲	FGA Sand	ND	Not Detected
□			1,1-DCA > 0 ug/L
□			1,1-DCA > 20 ug/L
■			1,1-DCA > 40 ug/L



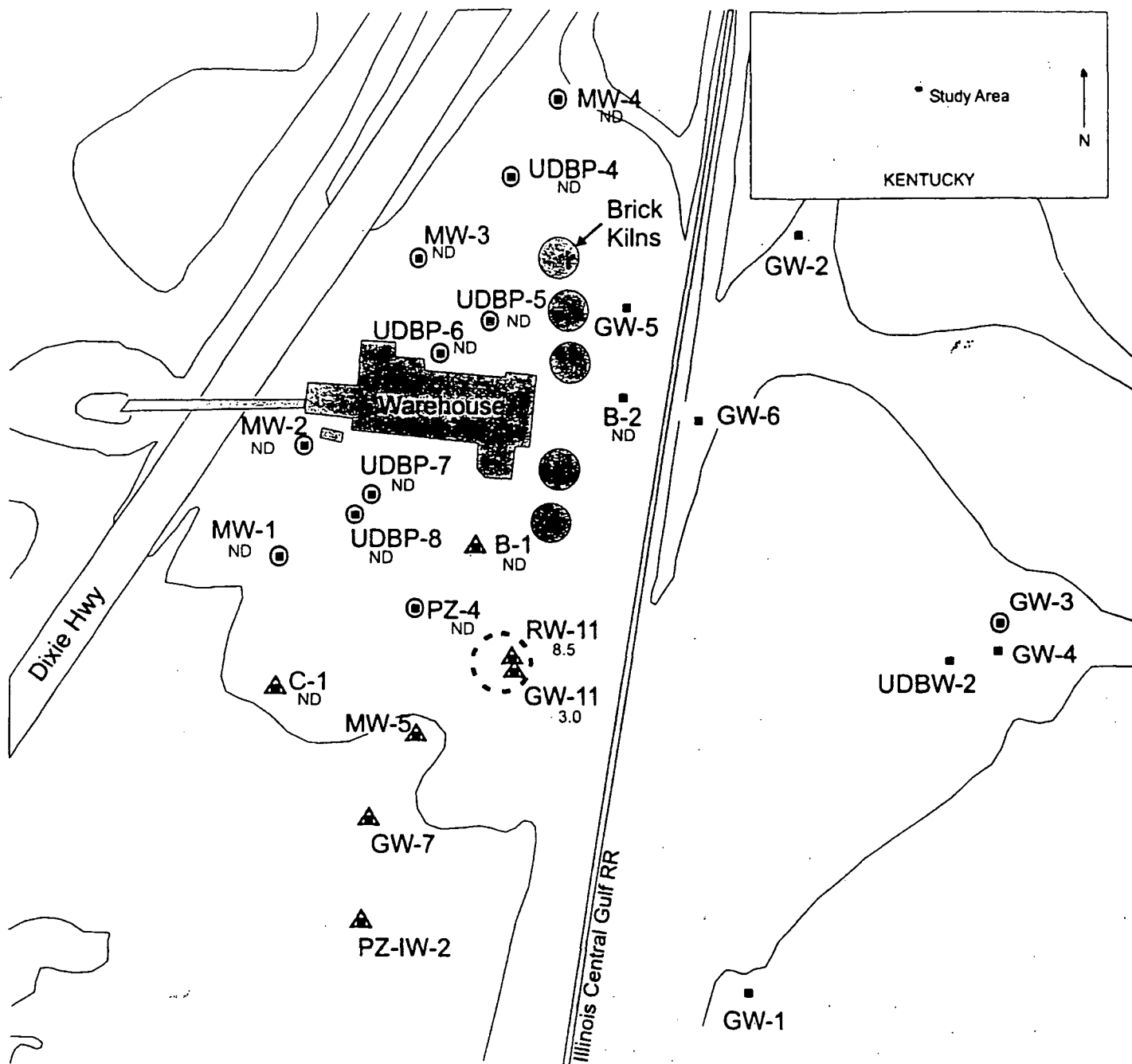
## EXPLANATION

⊙	CGA Well	10	Trans-1,2-DCE in Groundwater (ug/L)
■	FGA Well	10	1,1-DCE in Groundwater (ug/L)
▲	FGA Sand	10	1,2-DCA in Groundwater (ug/L)
ND			Not Detected
- - -			Extent of Trans-1,2-DCE, 1,1-DCE, and 1,2-DCA in Groundwater



## EXPLANATION

- |       |  |    |                                      |
|-------|--|----|--------------------------------------|
| ⊙     | CGA Well   | 10 | Chloroethane in Groundwater (ug/L)   |
| ■     | FGA Well   |    | Vinyl Chloride in Groundwater (ug/L) |
| ▲     | FGA Sand   |    | Not Detected                         |
| - - - | Extent of Chloroethane and Vinyl Chloride in Groundwater |    |                                      |



## EXPLANATION

⊙	CGA Well	10	Ethene in Groundwater (ug/L)
■	FGA Well	ND	Not Detected
▲	FGA Sand	- - -	Extent of Ethene in Groundwater

**Table 1.** Summary of sampling activities July-August 2000

Well	Stratigraphic Designation	Purging/Sampling Method	Comments
B-2	FGA	Grundfos Submersible Pump 0.5-1.0 gpm	None
MW-1	CGA		
UDBP-4	CGA		
UDBP-5	CGA		
UDBP-6	CGA		
UDBP-7	CGA		
UDBP-8	CGA		
GW-11	FGA Sand	Combination of submersible pump and bailer: Pump → Recharge → Repeat → Sample	Water level remained above screen
RW-11	FGA Sand		
PZ-4	FGA/CGA		
B-1	FGA Sand	Bailer	Insufficient recharge for submersible pump
C-1	FGA Sand		
MW-2	CGA	Bailer	Obstructions in well prevented the use of submersible pump
MW-3	CGA		
MW-4	CGA		
GW-7	FGA Sand	Bailer	Poor yield and slow recovery; Sampled for VOCs and field parameters only
PZ-IW-2	FGA Sand		
MW-5	FGA Sand	Not sampled	Rodent midden
UDBW-3	CGA	Not sampled	Inaccessible

**Table 2.** Gore-Sorber® deployment locations.

Gore-Sorber® only	Gore-Sorber® and Groundwater Sample
UDBW-2	GW-11
GW-3	PZ-IW-2
GW-4	UDBP-7
GW-1	MW-1
GW-6	B-1
GW-5	B-2
GW-2	GW-7
MW-5	—

**Table 3.** Oxidation-reduction parameters.

Wells	Dissolved Oxygen mg/L	Total Nitrate/Nitrite mg/L	NO2- mg/L	NO3- mg/L	Fe(II) mg/L	Sulfate mg/L	Methane µg/L
<i>FGA &amp; FGA Sand</i>							
B-2	0.47	ND	0.034	NA	0.97	89	22
GW-11	0.44	ND	0	NA	6.25	79	58A
RW-11	2.85	ND	0.101	NA	0.04	50	11
GW-7	0.24	—	0.035	NA	0.72	—	—
PZ-IW-2	0.97	—	0.166	NA	1.31	—	—
B-1	2.15	0.65	0.82	NA	0.35	59	5.4A
C-1	6.9	0.94	0.14	0.8	0	67	4.4
PZ-4	3.2	0.05	0.098	NA	0.34	73	16
<i>CGA</i>							
MW-1	5.26	0.34	0.064	0.276	0	59	ND
MW-2	4.04	0.46	0.037	0.423	0.31	61	ND
MW-3	3.92	0.96	0.043	0.917	0.5	52	0.34J
MW-4	5.57	2.6	0.03	2.57	0.23	73	4.2
UDBP-4	2.12	1.8	0.007	1.793	0.1	50	0.17J
UDBP-5	1.98	0.86	0.142	0.718	0	49	0.98J
UDBP-6	2.5	0.79	0.62	0.17	0.05	48	0.22AJ
UDBP-7	0.13	ND	0.088	NA	3	50	0.42J
UDBP-8	0.07	ND	0.18	NA	4.7	73	1.5

A = Average J = Approximate ND = Not Detected NA = Not Applicable



**Table 4.** Volatile organic compounds in groundwater. All data in µg/L

Wells	PCE	1,1,2-TCA	1,1,1-TCA	TCE	1,1-DCA	cis-1,2-DCE	1,2-DCA	trans- 1,2-DCE	1,1-DCE	CA	VC	Ethene	Ethane
<i>FGA &amp; FGA Sand</i>													
B-2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GW-11	ND	ND	ND	ND	1.9	0.6	1	4	ND	82	ND	3.0A	0.28AJ
RW-11	ND	ND	ND	65	48J	470	ND	10J	ND	ND	39J	8.5	ND
GW-7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	—	—
PZ-IW-2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	—	—
B-1	1	ND	0.5J	ND	ND	2	ND	ND	ND	ND	ND	ND	1.2AJ
C-1	ND	ND	11	14	33	65	ND	ND	ND	ND	ND	ND	1.2J
PZ-4	ND	4.2	4.8J	19	22	89	ND	3	ND	2.6	ND	ND	ND
<i>CGA</i>													
MW-1	ND	ND	1.4J	0.7J	8.4	21	2.7	ND	ND	ND	ND	ND	ND
MW-2	ND	ND	2.7	1.1	5.7	11	ND	ND	ND	ND	ND	ND	ND
MW-3	ND	ND	5	4J	11	35	ND	ND	ND	ND	ND	ND	ND
MW-4	ND	ND	0.8J	8	ND	6	ND	ND	ND	ND	ND	ND	1.0J
UDBP-4	ND	ND	1	6	2	8	ND	ND	ND	ND	ND	ND	ND
UDBP-5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UDBP-6	ND	ND	6	4	7	26	ND	ND	ND	ND	ND	ND	ND
UDBP-7	1.2	1.9	4.1J	16	22	93	5.4	3.2	0.7J	ND	ND	ND	ND
UDBP-8	ND	2.3	3.0J	12	23	93	9.2	2.8	ND	1.1	ND	ND	ND

A = Average J = Approximate ND = Not Detected NA = Not Applicable

**Table 5.** Volatile organic compounds detected in Gore-Sorbers. All data in µg per sorber.

Well	PCE	1,1,2-TCA	1,1,1-TCA	TCE	1,1-DCA	cis-1,2-DCE	1,2-DCA	trans-1,2-DCE	1,1-DCE
<i>FGA &amp; FGA Sand</i>									
B-2	ND	ND	ND	ND	0.07	0.05	ND	ND	ND
GW-11	0.17	ND	4.15	1.53	3.44	2.92	0.20	0.59	0.47
GW-11 (dupl.)	0.24	ND	1.54	0.94	2.68	2.14	0.09	0.35	0.11
GW-7	ND	ND	0.09	0.02	ND	ND	ND	ND	BDL
PZIW-2	ND	ND	BDL	ND	ND	ND	ND	ND	ND
B-1	0.04	ND	0.77	0.08	0.16	0.46	0.04	0.05	0.31
GW-5	ND	ND	ND	ND	ND	ND	ND	ND	ND
GW-6	ND	ND	ND	ND	ND	ND	BDL	ND	ND
GW-2	BDL	ND	ND	ND	ND	ND	ND	ND	ND
GW-4	0.24	ND	BDL	3.58	ND	0.49	BDL	0.07	BDL
UDBW-2	0.17	ND	BDL	19.8	ND	6.09	ND	0.12	ND
GW-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-5	0.19	0.07	6.57	8.60	3.69	6.77	0.30	0.24	0.34
<i>CGA</i>									
UDBP-7	ND	ND	0.14	0.21	0.32	1.32	0.03	0.10	BDL
MW-1	ND	ND	0.26	0.03	0.14	0.21	ND	BDL	BDL
MW-1 (dupl.)	ND	ND	0.28	0.04	0.14	0.23	BDL	BDL	BDL
GW-3	ND	ND	ND	ND	ND	ND	ND	ND	ND
<i>DL</i>	0.03	0.03	0.04	0.02	0.04	0.02	0.02	0.03	0.04

ND = Not detected BDL = Below Detection Limit DL = Detection Limit

**Table 6.** Equivalent TCE and 1,1,1-TCA concentrations calculated from TCE and cis-1,2-DCE and 1,1,1-TCA and 1,1-DCA concentrations, respectively.

Wells	TCE μg/L	cis-1,2- DCE μg/L	Total mol/L	Equivalent TCE μg/L	1,1,1- TCA μg/L	1,1-DCA μg/L	Total mol/L	Equivalent 1,1,1-TCA μg/L
<i>FGA &amp; FGA Sand</i>								
B-2	0	0	0	0	0	0	0	0
GW-11	0	0.6	6.19E-09	1	0	1.9	1.92E-08	3
RW-11	65	470	5.34E-06	702	0	48	4.85E-07	65
GW-7	0	0	0	0	0	0	0	0
PZ-IW-2	0	0	0	0	0	0	0	0
B-1	0	2	2.06E-08	3	0.5	0	3.75E-09	1
C-1	14	65	7.77E-07	102	11	33	4.16E-07	55
PZ-4	19	89	1.06E-06	140	4.8	22	2.58E-07	34
CGA	—	—	—	—	—	—	—	—
MW-1	0.7	21	2.22E-07	29	1.4	8.4	9.54E-08	13
MW-2	1.1	11	1.22E-07	16	2.7	5.7	7.78E-08	10
MW-3	4	35	3.91E-07	51	5	11	1.49E-07	20
MW-4	8	6	1.23E-07	16	0.8	0	6E-09	1
UDBP-4	6	8	1.28E-07	17	1	2	2.77E-08	4
UDBP-5	0	0	0	0	0	0	0	0
UDBP-6	4	26	2.99E-07	39	6	7	1.16E-07	15
UDBP-7	16	93	1.08E-06	142	4.1	22	2.53E-07	34
UDBP-8	12	93	1.05E-06	138	3	23	2.55E-07	34

**Table 7. Potential electron donors.**

Wells	Total Organic Carbon mg/L	Dissolved Organic Carbon mg/L	Ethyl Benzene µg/L	Total Xylenes µg/L
<i>FGA &amp; FGA Sand</i>				
B-2	9.9	9.3	ND	ND
GW-11	20	19A	45J	89
RW-11	17	14	ND	ND
GW-7	—	—	ND	ND
PZ-IW-2	—	—	ND	ND
B-1	9.1	7.4	ND	ND
C-1	18	13	ND	ND
PZ-4	20	14	ND	ND
<i>CGA</i>				
MW-1	14	10	ND	ND
MW-2	12	9	ND	ND
MW-3	8.4	7.9	ND	ND
MW-4	10	8.1	ND	ND
UDBP-4	8	7.6	ND	ND
UDBP-5	8.4	7.7	ND	ND
UDBP-6	6.8A	5.1A	ND	ND
UDBP-7	12	10	ND	ND
UDBP-8	12A	10	ND	ND

A = Average J = Approximate ND = Not Detected NA = Not Applicable

**Table 8.** Bioactivity parameters.

Wells	Alkalinity mg/L	Carbon Dioxide mg/L
<i>FGA and FGA Sand</i>		
B-2	347	138
GW-11	349	168
RW-11	374	125
GW-7	NA	123
PZ-IW-2	NA	140
B-1	257	86
C-1	475	NA
PZ-4	411	168
<i>CGA</i>		
MW-1	381	104
MW-2	370	113
MW-3	316	88
MW-4	316	72
UDBP-4	286	77
UDBP-5	279	112
UDBP-6	300	109
UDBP-7	322	127
UDBP-8	388	132

**Table 9.** Biological nutrients.

Wells	Ammonia mg/L	Total Phosphorus mg/L
<i>FGA and FGA Sand</i>		
B-2	0.17	0.18
GW-11	0.13	0.029
RW-11	ND	0.17
GW-7	—	—
PZ-IW-2	—	—
B-1	0.12	1.6
C-1	ND	3.2
PZ-4	0.091	1.8
<i>CGA</i>		
MW-1	ND	0.02
MW-2	ND	0.02U
MW-3	ND	0.3
MW-4	ND	1.1
UDBP-4	ND	0.1
UDBP-5	0.052	0.6
UDBP-6	ND	0.096A
UDBP-7	ND	ND
UDBP-8	0.094A	0.098A

**Table 10.** Chloride concentrations from October 1999 and July 2000.

Wells	Chloride October 1999 mg/L	Chloride July 2000 mg/L
<i>FGA and FGA Sand</i>		
B-2	—	1.9
GW-11	2.6	2.5
RW-11	—	14
B-1	—	3.9
C-1	—	80
PZ-4	—	13
<i>CGA</i>		
MW-1	14A	30
MW-2	16	12
MW-3	100	12
MW-4	—	2.9
UDBP-4	41	4.3
UDBP-5	—	4.2
UDBP-6	—	10
UDBP-7	120	4.6
UDBP-8	140	11
A = Average		

## **Exhibit 3**

### **Enhanced Bioremediation Pilot Project Report**



## ***NORTH WIND ENVIRONMENTAL, Inc.***

27 March 2002

NWE-02-064

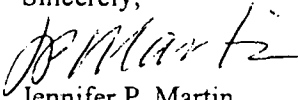
### Distribution

TRANSMITTAL OF THE PHASE I NSF SBIR FINAL REPORT AND THE BATTELLE PROCEEDINGS PAPER DESCRIBING THE RESULTS OF THE CHITIN-FRACING TEST CONDUCTED AT THE DISTLER BRICKYARD SITE

Please find the attached Phase I Final Report: Development of a Chitin-Fracing Technology for Remediation of Chlorinated Solvent Source Areas in Low Permeability Media. This report was prepared to fulfill the National Science Foundation's final requirement for completion of the Phase I test. It describes the activities conducted and results obtained during the Phase I laboratory experiments and a pilot-scale field test to support the evaluation of the innovative chitin-fracing technology for remediation of chlorinated solvent contamination at the Distler Brickyard Site. Also attached is the manuscript, entitled Enhanced CAH Dechlorination in a Low Permeability, Variably-Saturated Medium, which was submitted to the Remediation of Chlorinated and Recalcitrant Compounds Conference (sponsored by Battelle) to be held May 20-23, 2002. A presentation will be given at the conference and the paper, when accepted, will be published in the conference proceedings.

If you have any questions or comments regarding the attached documents, please contact me at (208)-528-8718 ext. 147 or [jmartin@nwindenv.com](mailto:jmartin@nwindenv.com), or Kent Sorenson at (208) 528-8718 ext. 129 or [ksorenson@nwindenv.com](mailto:ksorenson@nwindenv.com). Thank you for the opportunity to be of service.

Sincerely,



Jennifer P. Martin  
Hydrologist II

Enclosures

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NWE-ID-2002-024  
Revision 0

# **Phase I SBIR Final Report: Development of a Chitin- Fracing Technology for Remediation of Chlorinated Solvent Source Areas in Low Permeability Media**

**Kent S. Sorenson  
Jennifer P. Martin  
Rachel A. Brennan  
Gord H. Bures**

**March 2002**

# Phase I SBIR Biotechnology Final Report

Award Number 0109868

15 March 2002

## 1. Introduction

Chlorinated solvents are the most common class of ground water contaminants at hazardous waste sites in the U.S. In a list of the top 25 most frequently detected contaminants at such sites, the Agency for Toxic Substances and Disease Registry (ATSDR) found that 10 of the top 20 were chlorinated solvents or their degradation products, including two of the top three (NRC, 1994). In fact, the same survey found that the most common contaminant, trichloroethylene (TCE), is present more than 40% of National Priority List sites. Worse yet, remediation of ground water contaminated by these compounds often presents unique obstacles related to their inherent characteristics, including hydrophobicity and high density. Overcoming these obstacles often demands innovation and an interdisciplinary approach that integrates hydrology, geology, chemistry, microbiology, and economics. It is the purpose of the research described in this report to investigate the technical and commercial feasibility of just such an approach. In particular, *an innovative approach has been conceived to harness recent advances in the understanding of biodegradation processes involving chlorinated solvents for remediating residual contamination source areas in low permeability, saturated or variably saturated soils at a much lower cost than conventional methods.* The innovation involves delivering a novel electron donor (chitin) into induced fractures in low permeability soils with a proprietary delivery process (the FRAC RITE™ process, described below) to create and maintain nutrient-rich anaerobic conditions that will promote the long-term bioremediation of a chlorinated solvent dense nonaqueous phase liquid (DNAPL) source. Chitin is the structural component of the shells of crustaceans. Chitin is also present in many other living organisms, such as insects and mushrooms. Because it is present in so many different types of living organisms, chitin is the most plentiful natural polymer next to cellulose. The research described in this report investigated this innovative approach to applying the state-of-the-art understanding of biodegradation processes for the purpose of solving one of the most common and technically challenging problems currently facing industry, federal and state agencies, and environmental professionals.

### 1.1 FRAC RITE™ Process

Hydraulic fracturing is a process whereby a fluid is pumped into a borehole at a rate and pressure high enough to overcome the in situ confining stress and the material strength of a formation (i.e. soil or rock) resulting in the creation of a fracture. This process has been used for decades to enhance oil and gas production rates in wells where it would otherwise be uneconomical. When a hydraulically fractured well is produced, the induced fractures provide a conduit so that fluids can flow to the well at a greater rate than would otherwise be possible. The fractures also extend the "reach" of a well, such that an area can be drained with a smaller number of wells. In practice, a slurry mixture containing a proppant (sand) and a viscous fluid (guar gum and water mixture) is pumped under pressure into subsurface soils to create a fracture. After pumping, the sand holds the fracture open while an enzyme or chemical additive breaks

down the viscous fluid. The fluid subsequently drains out of the fractures, leaving only sand in the induced fractures.

The FRAC RITE™ process, based on the hydraulic fracturing techniques described above, was developed specifically for geo-environmental applications in unconsolidated, low permeability sediments. Fracturing is conducted using proprietary down-hole fracturing equipment designed for various soil types at shallow depths and low operating pressures (typically that of overburden pressure). The resulting network of sand-filled fractures that is created enables the expeditious recovery or in situ treatment of subsurface contaminants. The FRAC RITE™ process can also be used for incorporating biological amendments with the sand slurry to distribute these amendments in contaminated soils while simultaneously enhancing soil permeability.

## **1.2 Site Background**

The Distler Brickyard Site (located outside Louisville, KY, USA) contains the chlorinated aliphatic hydrocarbon (CAH) TCE at concentrations above the maximum contaminant level in groundwater. The presence of reducing conditions and less chlorinated degradation products cis-1,2-dichloroethene (cis-1,2-DCE), vinyl chloride (VC), and ethene indicates that biodegradation via anaerobic reductive dechlorination (ARD) was occurring naturally in the system. However, the rate and extent of ARD appeared to be limited by a lack of available electron donor. For this reason, a remediation technology that enhanced natural ARD via electron donor addition was hypothesized to be a viable method for reducing CAH concentrations to acceptable levels.

Remediation of CAHs at the Distler Site presents a number of challenges: 1) contamination is present in low permeability sediments, 2) the zone of contamination is variably saturated depending on seasonal changes in precipitation, and 3) available funding for remediation is limited. In order to deal with these challenges, a low-cost, low-maintenance remedy that was effective under variably saturated conditions was required. A novel approach was conceived that uses a solid phase electron donor emplaced as a sand-slurry mixture into the formation using the FRAC RITE™ process described above. In this particular application, chitin (JRW Technologies, Inc.) is incorporated with the sand in the fractures as an electron donor for ARD of CAHs.

The use of chitin in this application is an attractive approach because it potentially addresses all of the constraints presented above. Once emplaced in the formation, the chitin is degraded slowly, producing a relatively long-lived source of nitrogen and electron donor in the form of volatile fatty acids (VFAs) for ARD. Chitin is effective under the variably saturated conditions of this unique system; significant concentrations of VFAs are released only when the chitin is saturated, the same conditions under which CAHs are mobilized and must be degraded. Under unsaturated conditions, VFA production is slowed, thus the electron donor is available only when necessary and the longevity of chitin in the subsurface is maximized. Finally, the use of chitin is also attractive due to its availability and cost. Chitin is the most plentiful natural biopolymer in the world next to cellulose and thus is available at a low cost.

### 1.3 Phase I Objectives

For the reasons stated above, it was determined that the use of the chitin-fracing technology for enhanced ARD of CAHs might be an effective remediation technology to address the particular constraints that exist at the Distler Site, and many other similar sites – residual contamination present in low-permeability, variably saturated sediments. A research plan was designed to test the applicability of the chitin-fracing technology. This research had the following objectives as stated in the Phase I Small Business Innovation Research/Biotechnology Proposal (award number 0109868):

“The overall goal for this Small Business Innovation Research Phase I Project is to facilitate the maturation of this remediation approach to the point that it can be evaluated thoroughly at the field scale (the field-scale work would comprise a Phase II proposal). Meeting the technical objectives of the proposal will satisfy three goals. The first goal is to quantify the effectiveness of chitin as an electron donor facilitating reductive dechlorination of tetrachloroethylene (PCE) and TCE. This study showed that chitin held the most promise for this application. The research proposed herein would quantify the benefits of chitin as an electron donor. Two technical objectives for this goal are to evaluate the ability of chitin to promote and sustain reductive dechlorination under a variety of soil and groundwater conditions and the ability of the fatty acids and the ability of alcohols generated by biodegradation of chitin to increase the solubility/bioavailability of chlorinated solvent DNAPLs.

“The second major goal of the proposed research is to incorporate chitin into a delivery system designed for low permeability soils. Delivery of materials into low permeability soils is one of the key technical challenges for remediating such sites, and is critical to successful commercialization. It is proposed to integrate the chitin into the sand slurry used in the FRAC RITE™ process for soil fracturing. Amendments previously incorporated into the process include surfactants, slow release oxygen compounds, and biological nutrients. Given this, it is believed that incorporating chitin is quite feasible. It will be necessary, however, to investigate the interaction between the chitin and the guar polymer currently used in the FRAC RITE™ process. Some optimization of the mixture, and perhaps the timing of introduction will be necessary to ensure successful delivery of the chitin in the field.

“The third goal for the proposed research is evaluation of the delivery method in the field. It must be determined whether the chitin can be emplaced in a manner that facilitates dechlorination on a scale sufficient for the approach to be commercially viable. An appropriate field site for this research has been selected and the appropriate U.S. EPA and State Remedial Project Managers have provided written support. The purpose of the FRAC RITE™ process is to create highly permeable, sand filled fractures in low permeability soils to enable in situ treatment of contaminants trapped in the low permeability soils at much greater rates than conventional technologies. The extent to which the process creates a network of high permeability fractures at a field site will be evaluated through standard aquifer test methods. Perhaps more importantly, the distribution of chitin in the induced fracture network must be evaluated. This will be done through monitoring changes in oxidation-reduction (redox) conditions and chemical oxygen demand in the vicinity of the injection well.”

## **1.4 Summary of Research Tasks**

In order to address the above objectives, a research plan was developed that consisted of three tasks:

Task 1 – Evaluate the effectiveness of chitin as an electron donor for chlorinated solvent degradation through the use of laboratory column studies.

Task 2 – Determine whether chitin can be incorporated into the FRAC RITE™ process through the use of laboratory tests. Specifically, the two issues to be tested are whether chitin is compatible with the guar gel, and determining the maximum chitin: sand that the slurry solution can accommodate.

Task 3 – Demonstrate that chitin can be delivered to a low permeability formation on a scale relevant to site remediation through the use of a pilot-scale field test.

In addition to the tasks planned in the proposal and described above, supplemental funding provided by the U.S. EPA Technical Support Project (National Exposure Research Laboratory, Las Vegas, NV) and Region 4 (Atlanta, GA) made it possible to perform additional work in support of this project. This included the cost of tiltmeter monitoring during the fracturing and subsequent data analysis to model the distribution and orientation of the newly formed fractures in the subsurface (described in Section 2.3.2), and the analytical costs of the chloroethene and ethene/ethane/methane analyses, which were included to monitor the effect of the chitin emplacement on enhanced dechlorination of TCE.

## 2. Methods

As stated in the previous section, this research consisted of three tasks. The following sections describe the specific methods used to accomplish each of these tasks.

### 2.1 Task 1 UIUC Lab Study

Column studies were performed by University of Illinois at Urbana-Champaign (UIUC) to evaluate the ability of chitin to enhance the dissolution and dechlorination of PCE. Continuous-flow and semi-batch columns packed with chitin and sand were used to evaluate chitin as a potential carbon source for the remediation of both dissolved and DNAPL sources of PCE. The following anaerobic cultures were added to the columns used to evaluate ARD: the pure culture, *Desulfuromonas* strain BB1, which reductively dechlorinates PCE to *cis*-DCE (Löffler et al., 1998); a mixed culture enriched from Sangamon River sediments (Piatt County, IL), also capable of reducing PCE to *cis*-DCE; and a mixed culture enriched from Copper Slough sediments (Champaign County, IL), capable of reducing PCE to VC. Methods for the analysis of chloroethenes, methane, and VFAs have been presented previously (Brennan et al., submitted 2001).

To evaluate the effects of groundwater flow on the fermentation of chitin and the dissolution of PCE without dechlorinating cultures, experiments were performed in a continuous flow column system (Brennan et al., submitted 2001). The first column (chitin column) was packed with a mixture of 27.3-g chitin and 375.6-g sand, giving a ratio of chitin to sand of approximately 1:14 by mass. The second column (DNAPL column) was packed with sand and loaded with neat PCE to achieve a residual DNAPL saturation of 15%. The third and fourth columns were packed with sand only. After column preparation, groundwater was pumped through all four columns in series at a rate of 0.14 ml/min, giving retention times of 1, 1/2, 1/2, and 2 days for the first, second, third, and fourth columns, respectively (4 days cumulative retention time for the entire system). An identical set of columns without chitin served as a control to evaluate the dissolution of PCE in the absence of chitin. Aqueous samples were collected from the end of each column every 3 to 5 days and analyzed for CH<sub>4</sub>, H<sub>2</sub>, pH, VFAs, and chloroethenes. The columns were evaluated over a period of 101 days.

To uncouple the effects of chitin loading concentrations and groundwater conditions on the degradation of PCE, a series of experiments in semi-batch columns was performed. For each experiment, a column containing chitin (i.e., chitin column) was connected in series with another column containing PCE (i.e., PCE column). The chitin columns were packed with a mixture of sand, limestone, and chitin to yield mass ratios of chitin:sand of 1:10 and 1:5. The PCE columns were packed with sand, dechlorinating cultures, and PCE. The PCE was added to the columns either at the beginning of the experiment as neat PCE (1% residual), or during each sampling event from a stock solution to give a final concentration of 2.5 mg/L in the PCE column. Groundwater was pushed through the columns every 2 days using a piston pump to exchange 1 pore volume. The water collected from the end of all PCE columns was tested for pH, VFAs, and chloroethenes. The columns were evaluated over a period of 30 days.

## 2.2 Task 2 Frac-Rite Lab Study

Laboratory testing was performed to determine the actual carrying capacity of a fracture slurry comprising 20-40 mesh size chitin and 20-40 API specification frac sand. Blender stall, gelation, and specific gravity testing were performed using several guar and enzyme breaker over a range of pH values until a maximum concentration of pumpable chitin and sand was determined. The basic procedure consisted of adding incremental amounts of chitin to the sand slurry in a blender until the solution caused the blender to stall. Based on previous research performed by Vanson (chitin manufacturer), chitin was expected to be compatible with the guar slurry. For this reason, no additional compatibility testing studies were performed.

## 2.3 Task 3 Field Study

A field test was designed and conducted in the suspected CAH source area (Figure 1) to address Objective 3 above – to determine if chitin could be emplaced into a low permeability formation using the FRAC-RITE™ process. The location of the pilot test was moved from the original location described in the proposal downgradient of the source area to the source area due to higher water levels observed in the source area at the time of the monitoring well installation. The basic components of the field test consisted of the following: 1) well installation, 2) pre-fracing slug testing, 3) pre-fracing baseline sampling, 4) fracing and chitin emplacement, 5) tiltmeter monitoring during fracing, 6) post-fracing slug testing, 7) pumping test, and 8) post-fracing monthly groundwater monitoring.

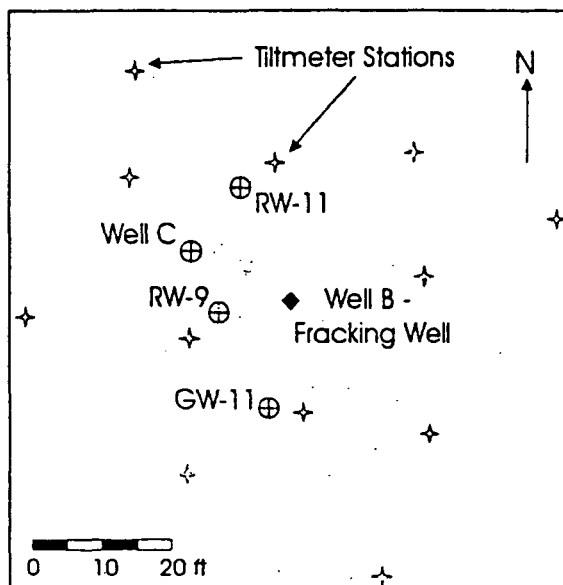


Figure 1. Source area well locations.



### 2.3.1 Hydraulic Fracturing

Hydraulic fracturing and chitin emplacement were conducted in a single well, Well B, which was drilled as part of the fracing activity (Figure 1). Three fracture zones were created at the following depths below ground surface in Well B: FWB-1 (25 ft), FWB-2 (33 ft), and FWB-3 (38 ft) (Figures 2 and 3).

The first fracture (FWB-1) was initiated in silty sand at a depth of 25 ft below the ground surface. There was some uncertainty as to the integrity of the seal created in the borehole due to the dense soil conditions encountered at this depth. Approximately 250 gallons of fracture slurry were pumped at FWB-1, of which approximately 200 gallons were placed as a discrete fracture. It is estimated that no more than 50 gallons of fracture slurry leaked to the surface through an annular vent to the borehole. The unadjusted (for losses) fracture initiation pressure was 180 psi at an average fracture slurry pumping rate of 12 gpm. Pressure monitoring indicated that some pump cavitation occurred during pumping, perhaps due to the low pumping rate (Figure 3). The amount of chitin and sand successfully placed in the fracture is estimated to be 80 lbs and 400 lbs respectively (Table 1).

Soil fracturing was commenced at FWB-2 in clay soils at a depth of 33 ft below the ground surface. It was decided to incorporate slightly more sand (550 lbs) in the fracture slurry because of the greater than expected carrying capacity of the base gel observed during the first batch mix. Incorporation of the extra sand resulted in a total batch mix of 275 gallons of fracture slurry for FWB-2. This entire volume of fracture slurry was successfully pumped into the clay soil without any leakage. The unadjusted fracture initiation pressure for FWB-2 was 235 psi at an average slurry-pumping rate of 26 gpm. The slurry-pumping rate was increased relative to that of FWB-1 in order to reduce the risk of pump cavitation. Pressure monitoring indicated a relatively constant fracture propagation pressure of 75 psi, which gradually declined to 50 psi near the end of pumping (Figure 3). The amount of chitin and sand successfully placed in the fracture is estimated to be 100 lbs and 550 lbs respectively (Table 1).

The final fracture (FWB-3) was initiated in clay soil at a depth of 38 ft below the ground surface. The amount of sand and chitin incorporated into the fracture slurry was again increased to take advantage of the carrying capacity of the base gel. The resulting fracture slurry was noticeably thicker than previous batches formulated. A total volume of 300 gallons of fracture slurry was successfully pumped into the clay soil without any loss of slurry due to leakage. The unadjusted fracture initiation pressure for FWB-3 was 200 psi. The fracture propagation pressure was a constant 75 psi during the pumping event (Figure 3). The amount of chitin and sand successfully placed in the fracture is estimated to be 145 lbs and 600 lbs respectively (Table 1).

**Table 1. Operating parameters of fracture placement.**

<i>Fracture No.</i>	<i>Depth (ft bgs)</i>	<i>Peak Pressure* (psi)</i>	<i>Soil Type</i>	<i>Chitin &amp; Sand Placed (lbs)</i>	<i>Placement Efficiency (%)</i>
FWB-1	25	180	silty Sand	80:400	80
FWB-2	33	235	silty Clay	100:550	100
FWB-3	38	200	silty Clay	145:600	100

\* Pressure required to initiate fracture in soil (unadjusted for system pressure losses)

### **2.3.2 Geophysical and Hydrologic Monitoring**

Geophysical and hydrologic monitoring were used to determine the effective radius of the fracturing and the effect of the fracturing process on the permeability and connectivity of the formation (Objective 3). Geophysical monitoring consisted of the use of an array of tiltmeter monitoring stations to infer the radius of influence of the fracturing. The use of tiltmeters was not included in the original scope of the Phase I proposal due to budgetary constraints; however, the data were determined to be very useful to the evaluation of this technology at the Distler Site. For this reason, the U.S. EPA's Technical Support Project (National Exposure Research Laboratory, Las Vegas, NV) provided the funding for the tiltmeter monitoring and modeling. Hydrologic monitoring consisted of the use of slug tests and a pumping test to measure changes in aquifer permeability and connectivity due to the fracturing.

Remote monitoring of fractures using proprietary tiltmeter geophysics was used to collect the geophysical data necessary to model the orientations and geometry of the individual fracture zones. Tiltmeters are highly sensitive instruments (microradian resolution) used to measure the minute ground surface deformations created during the fracturing process. The direction and magnitude of ground surface deformation ('tilt') measured by tiltmeters is used to determine the shape, thickness, effective radius, and orientation of fractures in the subsurface. Fracture mapping was conducted using surface-mounted ES Model 700 biaxial tiltmeters. An array of 12 tiltmeter stations surrounding the fracturing well (Well B) was used (Figure 1).

# CONFIGURATION OF FRACTURES PLACED AT DISTLER BRICKYARD SITE

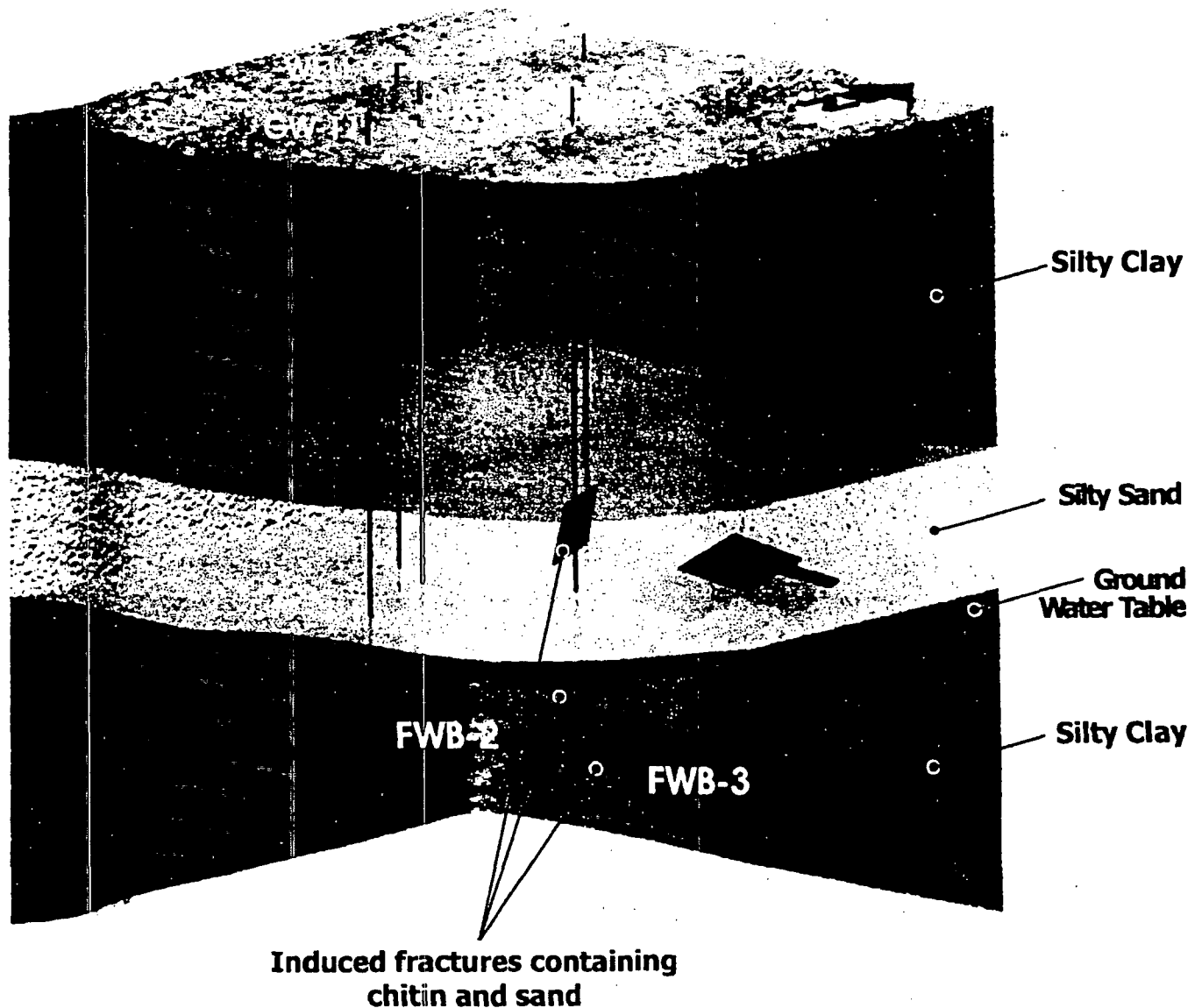
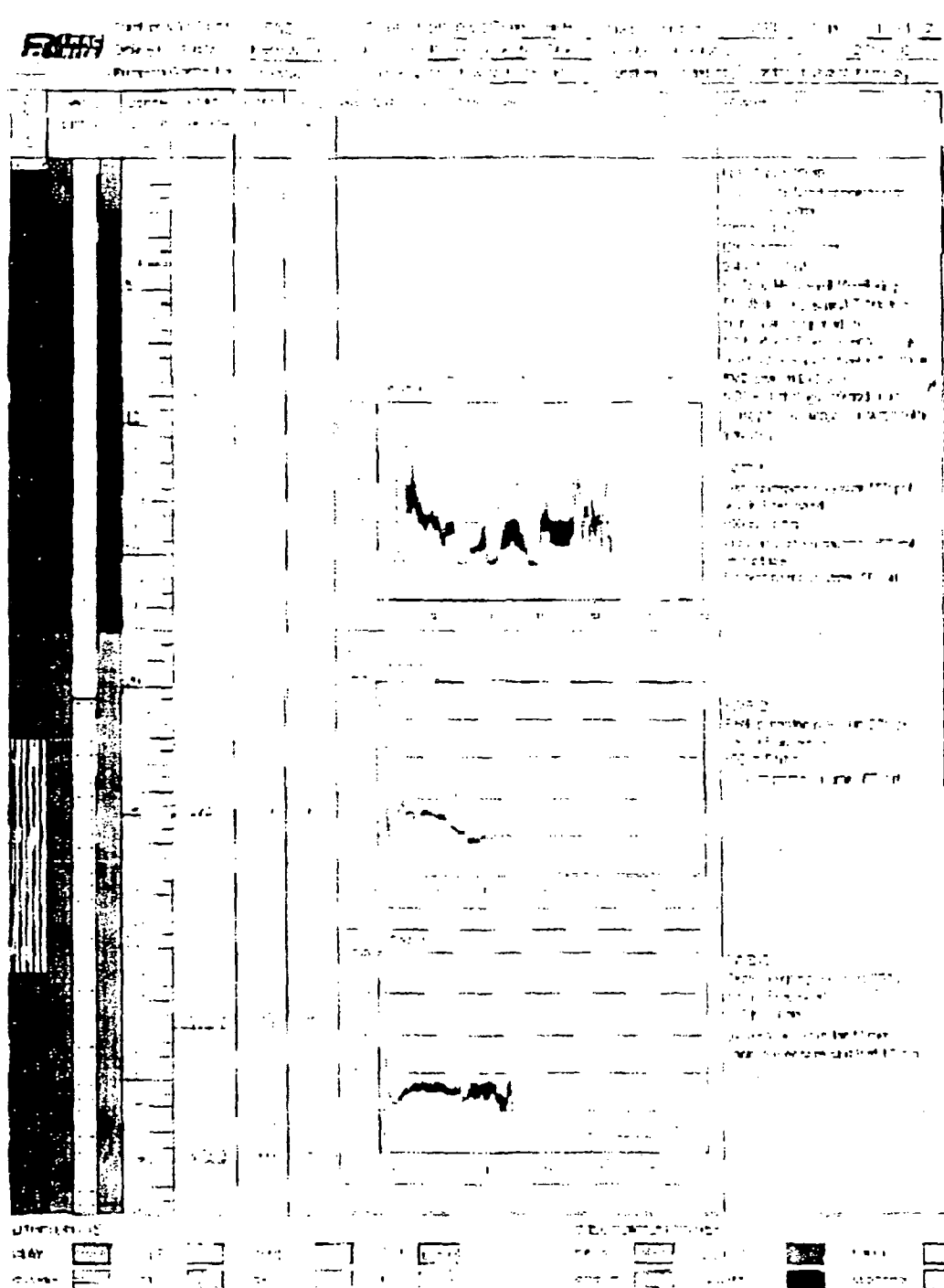


Figure 2

Three-dimensional representation of  
fractures induced in subsoils at  
Fracture Well FWB

**FRAC  
RITE**  
ENVIRONMENTAL LTD.



**Figure 3. Well log (partial) for Well B showing the locations of the three fracture zones and the pressure-time plots for each frac.**

Prior to fracturing, tiltmeters were aligned along north-south axis and electronically leveled. Tiltmeter input parameters (soil rheological constants, depth, spacing, etc.) were entered into a laptop computer and connected to the tiltmeters using cables. Data loggers were set to continuously record data approximately 30 minutes prior to each fracturing event to obtain a baseline signature and during each fracturing event to characterize the orientation and geometry of each of the newly created fractures. Tiltmeter signal data were modeled using geophysics based on analyses of soil stress, strain, and displacement induced by a sand-filled fracture intrusion into soils. The analyses are based on equations presented in Yang and Davis (1986).

Pre- and post-fracturing slug tests were performed in Well C in order to determine whether fracturing enhanced the permeability of the formation in the Well C area. The slug tests were performed by adding a slug of deionized water to Well C and monitoring the fall in water level over time using electronic water level indicators. The tests were complete when the water level returned to its pre-test level. In the pre-fracturing test (conducted in October 2001), 3 gallons of deionized water were added to Well C, which produced an approximately 0.6 ft increase in water level. In the post-fracturing test (conducted in January 2002), 4 gallons of deionized water were added which produced an approximately 3 ft increase in water level. Hydraulic conductivity values were derived from the results of the slug tests using the AQTESOLV software program; the system was modeled as an unconfined aquifer using the Bower and Rice (1976) solution.

A pumping test was used to assess the connectivity of the fracturing well (Well B) to the surrounding monitoring wells qualitatively. Well B was pumped intermittently for a period of approximately 5.5 hours (continuous pumping could not be sustained due to the relatively low yield of the formation), and a total of approximately 84 gallons was pumped from Well B. The drawdown and recovery in surrounding monitoring wells GW-11, RW-9, Well C, and RW-11 were monitored using electronic water level indicators.

### 2.3.3 Geochemical Monitoring

Groundwater sampling was conducted both prior to (baseline sampling) and following chitin emplacement on a monthly basis. The analytes consisted of electron donor parameters (chemical oxygen demand [COD] and the individual VFAs), redox parameters (nitrate, ferrous iron, sulfate, and methane), and ARD parameters (chloroethenes and ethene, chloroethanes and ethane). Purging was performed using either a disposable bailer or a submersible pump, depending on the maximum achievable flow rate at each well. Where the flow rate was sufficient to sustain pumping (RW-9, RW-11, Well C, and Well B) the pump was used to purge the well. In all cases, the well was pumped dry and allowed to recover slightly to provide sufficient water for sampling. Where the flow rate was not sufficient to sustain pumping (GW-11) a disposable bailer was used for purging. The only exception to this was the January 2002 sampling round; the water level in GW-11 had increased significantly from previous levels and GW-11 was purged using the pump. In all cases, sampling was performed using disposable teflon bailers.

Ferrous iron and nitrate analyses were performed in the field immediately after sample collection using field test kits. Sulfate and COD analyses were performed at the end of the

sampling week, also using field test kits (as described in Bullock et al., 2000 and Sorenson, 2000). VFA analyses were performed by UIUC as described in Brennan et al (submitted, 2001). Chloroethene and ethene/ethane/methane analyses were not included in the original research plan presented in the Phase I proposal; however, the data were determined to be important to the evaluation of the performance of the chitin-fracing technology at the Distler Site. For this reason, U.S. EPA Region 4 (Atlanta, GA) provided the funding to cover the cost of these analyses. Chloroethene and ethene/ethane/methane analyses were performed by the U.S. EPA laboratory in Athens, GA, using standard methods (GC-MS and GC-FID, respectively).

### 3. Results and Discussion

The results and discussion are presented in the context of each of the three tasks: Task 1 – UIUC Lab Study (Section 3.1), Task 2 – Frac Rite Lab Study (Section 3.2), and Task 3 – Field Study (Section 3.3).

#### 3.1 Task 1 – UIUC Lab Study

The Task 1 laboratory column studies were performed to evaluate the ability of chitin to enhance the dissolution and biodegradation of PCE. The non-dechlorinating continuous columns were used to evaluate whether chitin fermentation products enhanced the dissolution of PCE. As shown in Figure 4 by the production of VFAs, an active, fermentative microbial community was readily apparent throughout the continuous-flow column experiment. The dominant VFA produced during chitin fermentation was propionate, with an average concentration of 9.3 mM in the chitin column effluent throughout the entire experiment. Other VFAs produced were isovalerate, isobutyrate, and isocaproate, with average concentrations throughout the experiment of 3.3, 0.6, and 0.5 mM, respectively. Acetate and succinate were also detected, although at much lower concentrations, and only for brief periods. VFAs like isovalerate (with seven carbons) have the potential to act as surfactants with PCE and increase dissolution rates (Ellis et al., 1984, Martel et al., 1993). Figure 5 shows that in the presence of chitin fermentation products, dissolved PCE concentrations in the effluent of the active DNAPL-column were greater than in the control column (without chitin). After 101 days, 34.7% more PCE mass was dissolved out of the active column than out of the control. These results indicate that the chitin is having a surfactant-like effect and is enhancing the dissolution of PCE. The implication of this observation is that the use of chitin during bioremediation of chlorinated solvent source areas may significantly reduce the timeframe required for remediation.

Propionate has the potential to be an excellent electron donor for reductive dechlorination since it is typically oxidized to acetate and hydrogen under low hydrogen partial pressures. Dechlorinating bacteria are known to be excellent hydrogen consumers capable of maintaining the low hydrogen concentrations required to make propionate oxidation thermodynamically favorable (Löffler et al., 1999). The mass of propionate produced during this experiment was theoretically enough to reduce all of the PCE DNAPL to ethene (assuming an electron donating capacity of  $12 e^-$  per mole propionate). The presence of methane indicated that the system conditions were indeed favorable for reductive dechlorination of PCE. Mass balance calculations revealed that 94.7% of the chitin as carbon had been degraded into VFAs (93.8%) and methane (0.9%) by the end of the experiment. Thus, not only was DNAPL dissolution enhanced in the absence of dechlorinating cultures, but the conditions necessary for dechlorination were established.

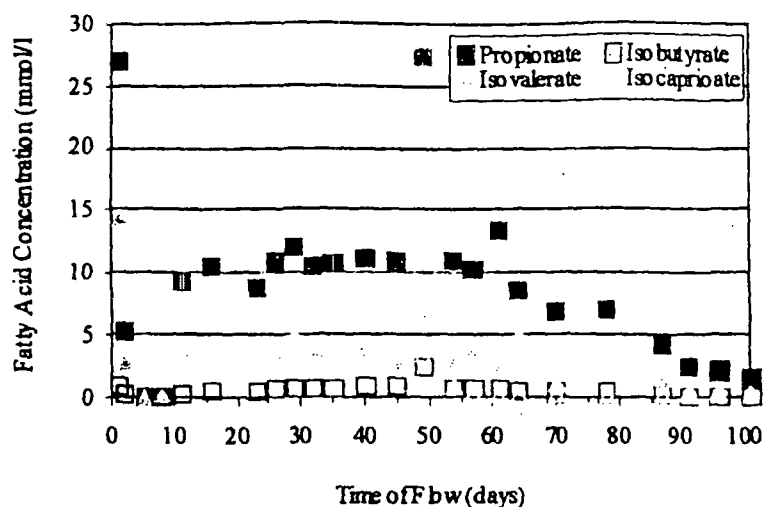
Semi-batch columns were used to evaluate the ability of chitin to support dechlorination. Natural groundwater was exchanged in the semi-batch columns for a total of 15 pore volumes. By the second pore volume, VFAs concentrations were observed to increase in all columns. Figure 6 illustrates a typical VFA profile from the effluent of a semi-batch column containing chitin at a ratio of 1:5 with sand. For all columns, propionate was the dominant fatty acid

produced, with concentrations generally sustained between 2-6 mM and 6-10 mM for chitin:sand ratios of 1:10, and 1:5, respectively. In addition to propionate, isovalerate, valerate, isobutyrate, acetate, and lactate were also detected, but at lower concentrations ( $< 2$  mM).

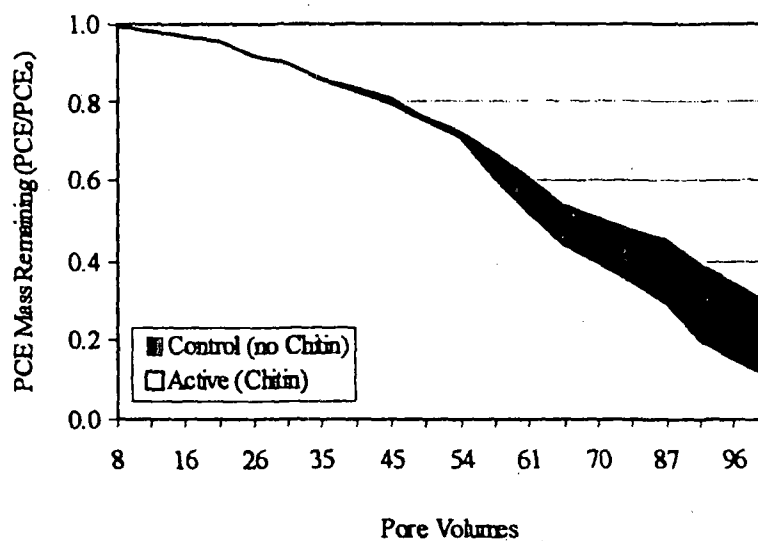
Chitin fermentation products supported dechlorination activity in all of the semi-batch columns containing dechlorinating cultures. PCE was reduced to trichloroethene (TCE), cis-dichloroethene (DCE), and vinyl chloride (VC) in these experiments. The lack of complete dechlorination to ethene was simply a function of the capabilities of the supplementary dechlorinating cultures used. It is expected that if supplementary cultures with VC-degrading ability were inoculated into the columns, ethene production would be supported. The most dechlorination activity was observed in columns containing low concentrations of chitin (1:10) and low concentrations of PCE (2.5 mg/L). This could be due to the lower pH conditions that were observed in columns containing high chitin concentrations. Figure 7 illustrates the typical dechlorination products observed in the effluent of a semi-batch column fed 2.5 mg/L PCE. Higher VC concentrations at later pore volumes (i.e., at later times) indicate that dechlorination activity increased in the column with time.

The results of the column studies indicated that chitin enhanced the dissolution of PCE and that the products of chitin degradation supported dechlorination. After 15 pore volumes, all of the PCE was dechlorinated to VC. It is expected that complete dechlorination of PCE to ethene would have been supported by chitin fermentation products had a culture capable of VC degradation been used in the columns.





**Figure 4. Electron donor production from chitin fermentation observed in the effluent of the continuous-flow chitin column (Brennan et al., submitted 2001).**



**Figure 5. PCE mass remaining in the continuous-flow DNAPL column, indicating enhanced dissolution in the presence of chitin fermentation products (Brennan et al., submitted 2001).**

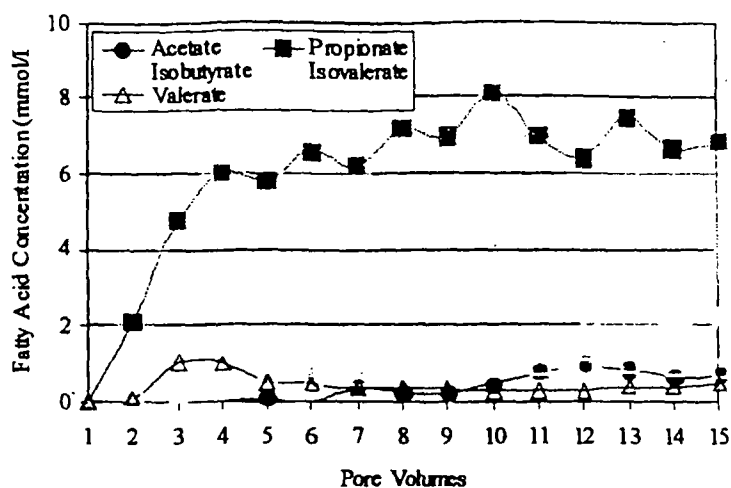


Figure 6. Electron donor production observed in the effluent of a semi-batch column containing chitin at a ratio of 1:5 with sand.

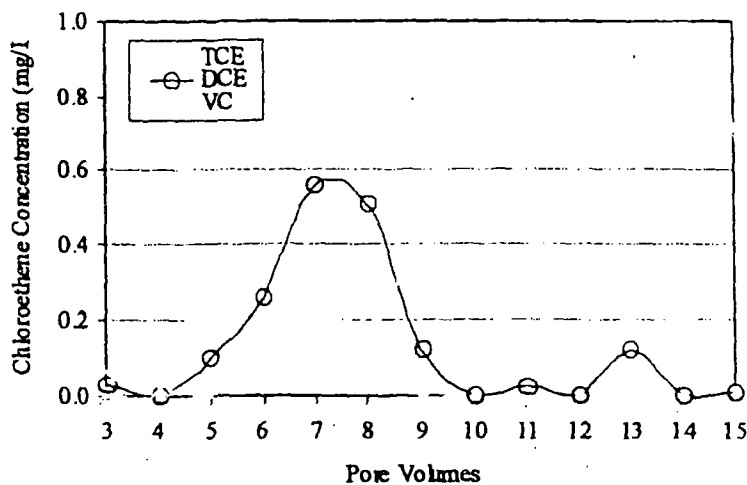


Figure 7. Dechlorination products observed in the effluent of a semi-batch column loaded with chitin at a ratio of 1:10 with sand and fed 2.5 mg/L PCE.

### 3.2 Task 2 – Frac-Rite Lab Study

Previous laboratory testing conducted by Vanson (chitin manufacturer) indicated that chitin/guar mixtures are compatible and that chitin will not interfere with the functionality of the guar gel. Subsequent laboratory studies indicated that chitin and sand could be successfully incorporated into a base gel to form a fracture slurry. As shown in Table 2, the recommended upper limit concentrations of chitin mixed with each of: plain tap water, hydroxypropyl guar (HPG) base gel, and HPG containing 20-40 frac sand are 65 kg, 55 kg, and 45 kg, respectively. The maximum recommended chitin to sand ratio achieved in laboratory testing was 1 to 4. The incorporation of chitin appears to be limited by its significant surface area, the large amount of 20-40 chitin particles, and low specific gravity. These characteristics give the chitin a large absolute volume, which limits the mass of chitin that can be mixed in liquid slurry. Given that the maximum chitin to sand ratio achieved in laboratory testing was 1 to 4, an operational ratio for chitin to sand of 1 to 5 was recommended for at least the first fracture initiated in the field. This corresponded to 100 lbs. of chitin and 500 lbs. of sand in a typical 250-gallon batch of fracture slurry.

**Table 2. Chitin limit concentrations in mixtures determined in lab studies.**

<i>Mixture Tested</i>	<i>Mass Chitin (kg)</i>	<i>HPG Base Gel (liters)</i>	<i>Tap Water (liters)</i>	<i>Mass Sand (kg)</i>
Chitin with Tap Water	65	None	1000	None
Chitin with HPG Base Gel	55	1000	None	None
Chitin with HPG Base Gel and 20-40 Frac Sand*	45	1000	None	200

\* Chitin to Sand ratio of approximately 1 to 4.

### 3.3 Task 3 – Field Study

This section presents the results of the field test in the context of the specific Task 3 objectives – to demonstrate that the fracturing results in an increase in the permeability and connectivity of the formation (Section 3.3.2), and that the chitin, once emplaced, creates a geochemical environment conducive to the dechlorination of CAHs (Section 3.3.3). In addition, additional data outside the original scope of the Phase I proposal, whose collection was made possible by supplemental funding from U.S. EPA, are presented to demonstrate the impact of the chitin-fracing technology to the dechlorination of CAHs (Section 3.3.4).

### 3.3.1 Fracture Mapping

The results of fracture mapping to determine fracture orientation and geometry are presented based on analysis of tiltmeter geophysical data. The collection of these data was made possible by additional funding provided by the U.S. EPA's Technical Support Project (National Exposure Research Laboratory, Las Vegas, NV). Tilt vectors measured at each tiltmeter station were used to model each fracture as a discrete planar feature. A three dimensional representation of the modeled fractures is presented in Figure 2. Pressure-time plots (shown in Figure 3) and slurry flow rate data were likewise considered in the interpretation of the tiltmeter data. These results are summarized in Table 3.

Fracture **FWB-1** was modeled as a single planar fracture dipping at an angle ("dip angle" or "dip") of 78 degrees from the horizontal. It exhibited an effective fracture radius of approximately 3.0 ft. and was interpreted to be 1.2 in. in thickness. The azimuth of the fracture plane (i.e. direction perpendicular to the dip direction) was 158 degrees. This fracture was the smallest of the three fractures placed, and also the most steeply inclined relative to the horizontal. The fracture appeared initially to propagate through the silty sand formation, and then partially intersected the borehole above the fracturing tool. This resulted in some slurry leak-off into the borehole annular space resulting in a smaller than predicted fracture.

Fracture **FWB-2** was modeled as a single, shallowly dipping, planar fracture having a dip angle of 22 degrees from the horizontal, an effective fracture radius of 13.9 ft., and a thickness of 0.9 in. The azimuth of the fracture was 106 degrees. Fracture **FWB-2** was the largest of the fractures placed. The tilt vector signature during fracture initiation and propagation in the silty clay soils appeared consistent with that of a predominantly horizontal fracture. The pressure-time data did not indicate any slurry leakage.

Fracture **FWB-3**, initiated in silty clay soils, was also modeled as a single, shallowly dipping, planar fracture. Its dip angle of 32 degrees from the horizontal was more than that of **FWB-2** but the fracture was predominantly horizontal. Its effective fracture radius was 12.7 ft., and it exhibited a fracture thickness of 1.4 in. The azimuth of the fracture was 101 degrees. Fracture **FWB-3** was an intermediate sized fracture. Its tilt vector signature during fracture initiation and propagation in the silty clay soils appeared consistent with that of a predominantly horizontal fracture. Its configuration and pressure-time plot signature were similar to that of **FWB-2**, which was also initiated in silty clay soils.

Figure 2 is a three-dimensional representation of the fractures in the subsurface based on the tiltmeter modeling results. As is indicated in Figure 2, **FWB-1** is much more steeply dipping and has a much smaller radius of influence than the other two fracs. This is because **FWB-1** was initiated in the silty sand unit while **FWB-2** and **FWB-3** were initiated in the underlying silty clay unit. Also, **FWB-2** and **FWB-3** have similar azimuth bearings (106 and 101 degrees, respectively) while **FWB-1** has an azimuth of 158 degrees, indicating that the propagation direction of the fractures in the two units was different. These results make the point that the propagation of fractures (direction and distance from initiation point) is influenced by the soil fabric and in situ soil stress conditions (degree of consolidation). This is a factor that must be

included in the design of future fracturing activities at the site in order to achieve the required distribution of electron donor in the subsurface.

**Table 3. Fracture characteristics determined from tiltmeter analysis.**

<i>Fracture and Depth</i>	<i>Fracture Fluid Volume (gallons)</i>	<i>Dip Angle (degrees)</i>	<i>Fracture Azimuth (degrees)</i>	<i>Fracture Thickness (in)</i>	<i>Effective Fracture Radius (ft)</i>
FWB-1 (25 ft)	250	78	158	1.2	3.0
FWB-2 (33 ft)	275	22	106	0.9	13.9
FWB-3 (38 ft)	300	32	101	1.4	12.7

NOTE - 1. Dip angle measured from horizontal. Dip direction is perpendicular to fracture azimuth.

2. Effective fracture radius defined as projection of inclined fractures to an equivalent radius in plan view.

### 3.3.2 Impact to Hydrologic System

The results of the pre- and post-fracturing slug tests performed at Well C were compared to determine the effect of the fracturing on the hydraulic conductivity of the formation in the Well C area (Figure 1), approximately 13 ft from Well B. The hydraulic conductivity values obtained from these slug tests were  $1.2 \times 10^{-5}$  cm/sec and  $1.1 \times 10^{-4}$  cm/sec for the pre- and post-fracturing slug tests, respectively. These results would appear to indicate that the fracturing process had increased the hydraulic conductivity of the formation by approximately an order of magnitude. However, in the time between the pre-fracturing (October 2001) and post-fracturing (January 2002) tests, the water level in Well C increased by approximately 1.7 ft due to seasonal variations in the water level. In the vicinity of Well C, the stratigraphy consists of a silty clay immediately above the shale bedrock; this silty clay is overlain by a silty sand. In the pre-fracturing test, the water level was only about 0.6 ft above the clay-sand contact, whereas in the post-fracturing test, the water level was about 2.3 ft above this contact. So it is possible that the post-fracturing test was dominated by the response of the sand unit, while the pre-fracturing test represents the combined response of the sand and silty-clay units, which would yield a lower overall hydraulic conductivity. Because of this issue, it is difficult given the available data to determine the effect of the fracturing alone on the hydraulic conductivity of the formation in the Well C area.

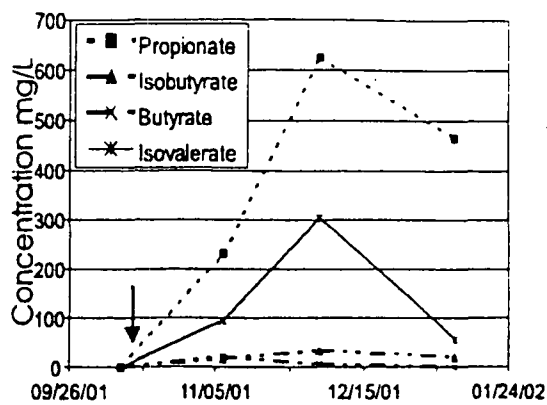
The fracturing process creates a network of highly-permeable sand-filled fractures. The propagation of these fractures is influenced by soil matrix properties (e.g. bedding planes) and in situ soil stresses (e.g. degree of consolidation) and thus fractures do not always form as radially symmetrical and horizontal 'pancakes' about the fracturing well. In order to infer the distribution and orientation of these fracture zones in the formation, a pumping test was used in addition to

the tiltmeter monitoring. A pumping test was performed to assess the relative connectivity of Well B to the surrounding monitoring wells. Results indicate that each well responded almost immediately to pumping in Well B, suggesting that a network of fractures connects the group of wells to Well B. As described above in Section 3.3.1, tiltmeter modeling results indicated that FWB-1 (25 ft) had an effective radius of 3.0 ft, FWB-2 (33 ft) had an effective radius of 13.9 ft, and FWB-3 (38 ft) had an effective radius of 12.7 ft. Given that the modeled effective radii of the three fractures (up to almost 14 ft) and the distances between Well B and the surrounding monitoring wells (9 – 15 ft), it is likely that the fracturing at Well B has increased the connectivity among the well network. While it is not possible to separate the effect of the fracturing from that produced by the increased water level from the available slug test data, given the radius of influence of the fractures predicted from the tiltmeter modeling results described above, and the connectivity of all four monitoring wells to Well B as indicated by the pumping test, it is likely that the fracturing process increased the hydraulic conductivity and connectivity in this area of the formation.

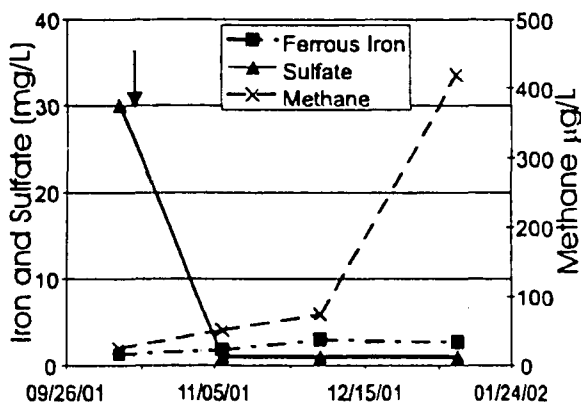
### 3.3.3 Impact to Geochemistry

Concentrations of electron donors to support ARD were monitored using a COD test kit and the concentrations of individual VFAs. Figures 8(a) and 9(a) present the concentrations of individual VFAs at Wells RW-9 and Well C, respectively. As shown in Figure 8(a), propionate was the dominant VFA observed in RW-9 and was present at a maximum concentration of around 600 mg/L. Isovalerate was also detected at RW-9 at concentrations as high as approximately 300 mg/L. These results are consistent with the laboratory column studies described above in which propionate is the dominant VFA and isovalerate the secondary VFA produced from fermentation of chitin. As seen in Figure 9(a), significant concentrations of VFAs were not present at Well C. Concentrations of butyrate of approximately 25 mg/L were observed in November 2001, but all VFAs had dropped below detection by January 2002. These results indicate that chitin was not distributed to the Well C area during fracturing and that transport of VFAs from chitin-filled fractures to Well C did not occur.

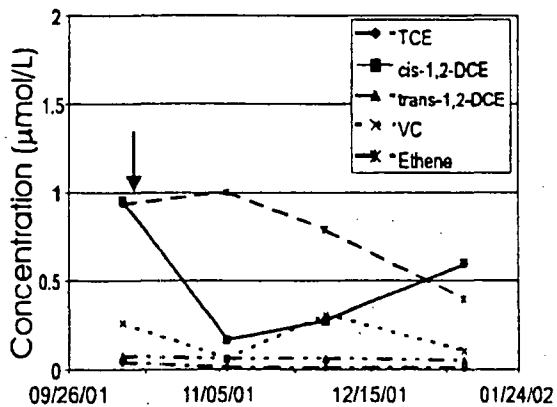
In order for complete ARD of CAHs such as TCE to proceed to non-chlorinated products, the redox conditions must be very reducing (i.e. methanogenic). Microorganisms obtain energy for new cells and for the maintenance of existing cells through the mediation of oxidation-reduction, or redox, reactions involving the transfer of electrons from an electron donor to an electron acceptor (Zehnder and Stumm, 1988; Pirt, 1975; and Bouwer 1994). In general, the electron donor is an organic compound while the electron acceptor is inorganic (Zehnder and Stumm, 1988). The free energy yielded by redox reactions varies substantially depending upon the electron acceptor. During respiration, microorganisms will preferentially utilize the electron acceptors yielding the greatest free energy (Bouwer, 1994). The order of preference for the most common inorganic electron acceptors is oxygen, nitrate, manganese-IV, iron-III, sulfate, and carbon dioxide. It should be noted that this is based on thermodynamic considerations only and that the kinetics of a given redox reaction can also be important (Zehnder and Stumm, 1988). Therefore, the dominant microbial community in a ground water system is largely dependent upon the distribution of electron acceptors. Where oxygen is



8(a)

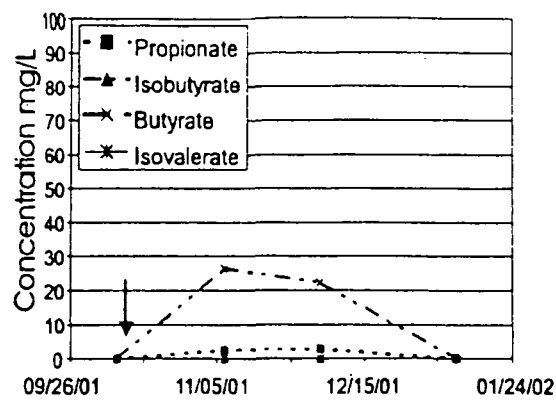


8(b)

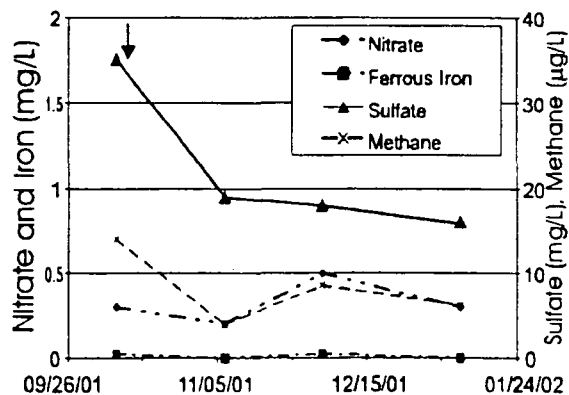


8(c)

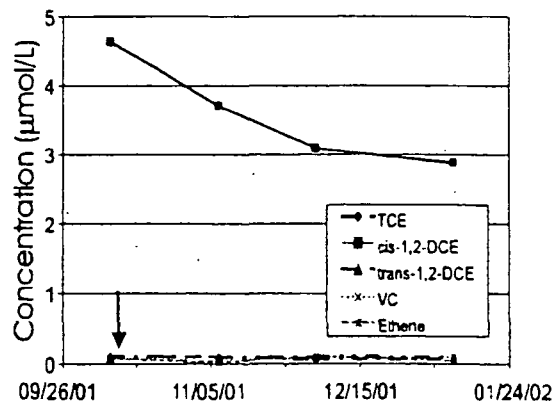
Figure 8. Electron donors (a), redox conditions (b), and ARD indicators (c) in Well RW-9. The arrow indicates the timing of chitin emplacement.



9(a)



9(b)



9(c)

Figure 9. Electron donors (a), redox conditions (b), and ARD indicators (c) in Well C. The arrow indicates the timing of chitin emplacement.



plentiful, aerobic bacteria will predominate; where oxygen is depleted, but nitrate is plentiful, nitrate-reducing bacteria will predominate; and so on.

Based on the common inorganic electron acceptors listed above, the redox conditions at a site can most easily be evaluated by measuring some subset of the following:

- dissolved oxygen: non-zero values indicate aerobic conditions
- nitrate: non-zero conditions indicate nitrate reduction is not complete
- manganese-II: non-zero values indicate reduction of manganese-IV is occurring
- iron-II: non-zero values indicate reduction of iron-III is occurring
- sulfate: non-zero conditions indicate sulfate reduction is not complete
- methane: non-zero values indicate reduction of carbon dioxide (methanogenesis)

The subset of these parameters used to determine redox conditions at the field site consisted of nitrate, ferrous iron, sulfate, and methane. Redox conditions in the fracing area were determined both before and following the chitin emplacement. As seen in Figure 8(b), prior to chitin emplacement ferrous iron was present in low but measurable concentrations (approximately 1.3 mg/L), sulfate concentrations were 30 mg/L, and methane was less than 40 µg/L. These data indicate that iron-reducing conditions, not reducing enough for complete ARD of TCE, existed at RW-9 prior to chitin emplacement.

After chitin emplacement, ferrous iron concentrations increased to exceed the range of the analytical method, sulfate concentrations dropped to below detection, and methane increased to almost 450 µg/L (Figure 8(a)). These trends indicate the onset of sulfate reduction and methanogenesis in the RW-9 area, suggesting that the presence of VFAs from chitin has resulted in the creation of a geochemical environment conducive to complete ARD of TCE.

In Well C prior to chitin emplacement, concentrations of nitrate were relatively low (0.3 mg/L), ferrous iron was below detection, sulfate was 35 mg/L, and methane was less than 15 µg/L (Figure 9(b)). These data indicate that conditions at Well C were mildly reducing (in the range of nitrate-reducing) prior to chitin emplacement. After chitin emplacement, sulfate did drop to about 16 mg/L; however, nitrate and methane remain consistent with pre-chitin values (Figure 9(b)). The presence of sulfate and the absence of methane following chitin emplacement indicate that the redox conditions necessary for complete ARD of TCE were not created in the Well C area. This is not surprising given that significant concentrations of VFAs were not observed at this well.

### **3.3.4 Impact to Dechlorination**

While not in the scope of the Phase I proposal, additional funding was obtained from the U.S. EPA Region 4 (Atlanta, GA) to monitor concentrations of TCE and degradation products cis-1,2-DCE, VC, and ethene during the field test in order to determine the effect of chitin emplacement on the ARD of TCE. Figure 8(c) presents the concentrations of chloroethenes in RW-9. Prior to chitin emplacement, cis-1,2-DCE was the dominant chloroethene, followed by significant concentrations of ethene and low levels of VC and TCE. The presence of cis-1,2-DCE and ethene at significant concentrations and the absence of TCE indicate that ARD of TCE

was already occurring to some extent at this location prior to chitin emplacement. After chitin emplacement, cis-1,2-DCE concentrations dropped and ethene became the dominant compound present, indicating enhanced ARD of cis-1,2-DCE. This is consistent with the drop in sulfate concentrations, which indicate that conditions were becoming favorable for complete ARD of TCE (Figure 8(b)). In the last two monitoring rounds, concentrations of cis-1,2-DCE have begun to rebound and ethene has dropped indicating that the enhanced ARD of cis-1,2-DCE may be declining and conditions are shifting back toward pre-chitin conditions. This is consistent with a decrease in the concentrations of VFAs in January 2002 (Figure 8(a)).

In Well C, cis-1,2-DCE was the dominant chloroethene prior to chitin emplacement; the other chloroethenes were present at relatively low concentrations ( $< 15 \mu\text{g/L}$ ) (Figure 9(c)). This is likely due to incomplete ARD of TCE to cis-1,2-DCE upgradient and subsequent transport of cis-1,2-DCE to the Well C location. After chitin emplacement, concentrations of cis-1,2-DCE dropped; however, significant concentrations of less-chlorinated degradation products VC and ethene were not produced (Figure 9(c)). These data indicate that ARD of cis-1,2-DCE was not enhanced significantly in the vicinity of Well C by the chitin emplacement. This is consistent with the relative absence of electron donors in the form of VFAs and the presence of sulfate indicating that conditions were not appropriately reducing for ARD to be energetically favorable.

## 4. Conclusions and Recommendations

Results from the Task 1 laboratory column study indicate that chitin is a viable electron donor and carbon source for the remediation of chloroethenes. Chitin fermentation products supported the dechlorination activity of supplementary cultures in all experiments. The slow and sustained production of VFAs from chitin could be a positive indication of the longevity of chitin in the field. Under the continuous-flow conditions tested in this study, chitin maintained reducing conditions and continued to produce VFAs for over 3 months. In addition, VFA "surfactants" produced from degradation of chitin were shown to increase the mass of DNAPL dissolved compared to a control without chitin. The implication of this effect is that, because of its surfactant-like properties, the use of chitin accelerates clean-up of a source area compared to an amendment without this capability where the rate of biodegradation may be limited by the rate of mass transfer to the aqueous phase where biodegradation takes place.

Results from the Task 2 laboratory testing indicated that 20-40 size chitin could be successfully incorporated into a water-based hydroxypropyl guar base gel and subsequently formulated into a fracture slurry containing 20-40 size sand. The chitin was found to be compatible with the guar gel and was determined to not interfere with the functionality of the guar. The maximum mass ratio of chitin:sand that was accommodated in the fracture slurry in laboratory tests was 1:4.

Hydrologic data, geochemical data, and ARD data were presented for two monitoring wells to describe the overall impact of the pilot-scale chitin emplacement on the hydrologic system, geochemical environment, and subsequent remediation potential of the chitin emplacement technology (Task 3). Based on the results of the slug tests and pumping test, fracturing appeared to increase the hydraulic conductivity in the Well C area although it is not possible to distinguish between the effects of the fracturing and the increase in water levels observed between pre- and post-fracturing testing. The results of the pumping test indicate that Well B is hydraulically connected to all of the surrounding monitoring wells. The high degree of connectivity in an otherwise low permeable system is likely due to the creation of highly permeable sand-filled fractures surrounding Well B.

Data indicate that significant concentrations of VFAs produced from the degradation of chitin were observed at RW-9 but not at Well C. This suggests that the propagation of chitin-filled fractures from Well B was not symmetrical about Well B, but was influenced by matrix properties (such as bedding planes) and in situ soil stress conditions (degree of consolidation). Where significant concentrations of VFAs were observed in RW-9, the redox conditions became strongly reducing (sulfate reduction and methanogenesis were stimulated). At Well C, where significant concentrations of VFAs were not observed, sulfate concentrations remained high and methane low. As very reducing (methanogenic) conditions are required for complete ARD of TCE, enhanced ARD was observed at RW-9 but not at Well C.

The results of this field pilot test indicate that chitin, where present, was able to affect the redox conditions and support enhanced ARD. Where chitin was distributed (RW-9 area) redox conditions became more reducing and enhanced ARD was observed. While significant

concentrations of VFAs persist at well RW-9 after 4 months, further monitoring is required to determine the longevity of chitin in the system. Where chitin was not distributed (Well C area), redox conditions were not impacted and enhanced ARD was not observed. While additional follow-on studies are required to determine the cost-effectiveness of full-scale operations, it appears that the chitin-fracing technology is a technically viable remediation technology for low permeability, variably-saturated systems.

The following are specific conclusions for each of the three tasks.

Task 1 –

- Chitin enhanced the dissolution of PCE in column studies indicating that it may cost-effectively accelerate clean-up of source areas.
- The dominant VFA produced from chitin fermentation was propionate, which has been shown to be an excellent electron donor for dechlorination.
- Chitin supported ARD in column studies; the extent of ARD was limited by the degradative ability of the cultures used.
- Slow and sustained production of VFAs is a positive indicator for the longevity of chitin in a field setting.

Task 2 –

- Chitin can be incorporated easily into the FRAC RITE™ process.
- Laboratory studies indicated that the maximum mass ratio of chitin to sand that the slurry solution can accommodate is 1:4.

Task 3 –

- Chitin was successfully delivered to the low permeability sediments present at the Distler Site.
- Chitin fermentation products impacted the geochemistry of the aquifer such that the conditions required for complete dechlorination of TCE were created.
- Chitin fermentation products, where present, supported the enhanced dechlorination of TCE.
- The propagation of fractures in the subsurface is not homogeneous about the fracing well and this issue should be considered during the design of the full-scale system in order to achieve the desired distribution of chitin in the subsurface.

The Phase I proposal stated that: "If the proposed Phase I research demonstrates 1) that chitin facilitates reductive dechlorination of PCE and TCE with efficiencies that make usage rates commercially feasible both by providing appropriate electron donors and by enhancing bioavailability, 2) that chitin can be successfully integrated into an established delivery method for low permeability soils, and 3) that the delivery method successfully distributes chitin in high permeability fractures at an appropriate field site, then the technology will be sufficiently mature to warrant a Phase II field research project." As discussed above, Phase I was quite successful in all of these respects. In fact, because of the U.S. EPA interest in the project we were able to

perform additional scope during Phase I and actually collect preliminary data demonstrating that after only a few months, chitin emplacement enhanced contaminant degradation in a field setting. Based on these results we are excited about moving to a Phase II project. As noted in the Phase I proposal, Phase II would focus "...on process longevity, including the closely related issues of microbial succession and microbial competition. Longevity is clearly of critical importance from the standpoint of commercialization because it determines the frequency at which additional chitin would need to be delivered to a site."

In addition to assessing process longevity, the Phase I results reveal that the non-uniform distribution of chitin due to non-homogeneous fracture propagation needs to be included in the design of a larger scale field test. While it is difficult to predict small scale heterogeneities in natural systems, assuming the fracture propagation is governed by site soil properties, it is not unreasonable to expect that fractures would propagate in similar directions when they are initiated in a single lithologic unit at a particular site. Thus, the preferential fracture propagations observed in the two hydrostratigraphic units (silty sand and silty clay units) at the Distler Site during the Phase I field test can be incorporated into the design of a larger scale Phase II test. Further developing the understanding of chitin distribution optimization, along with process efficiency and longevity during Phase II will maximize the commercial potential of this approach to remediating low permeability aquifers.

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## **Exhibit 4**

### **Work Plan for Full-Scale Enhanced Bioremediation Project**

## *NORTH WIND, Inc.*

8 April 2003

NWE-03-058

Mr. Femi Akindele  
US EPA Region 4  
61 Forsyth St SW  
Atlanta GA 30303

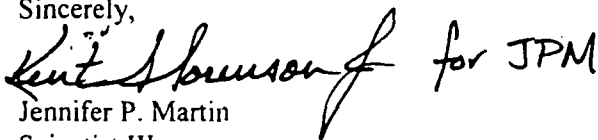
### TRANSMITTAL OF THE FINAL DRAFT OF THE WORK PLAN FOR PHASE II ACTIVITIES AT THE DISTLER BRICKYARD SITE, HARDIN COUNTY, KENTUCKY

Dear Mr. Akindele:

Based on the verbal approval provided by yourself and Ken Logsdon on April 3, 2003, we have finalized the Work Plan for Phase II Chitin/Fracing at the Distler Brickyard Superfund Site, Hardin County, Kentucky, and attached a copy for your records. This plan describes the field activities that will be conducted at the site during the Phase II implementation of the chitin/fracing technology at the Distler Brickyard Site. As discussed in our April 3 conference call, field activities will begin on April 14, 2003. The drilling/fracing component will be completed by May 9, however monitoring activities will continue throughout the Phase II project. We would welcome your visit to the site during any of these activities. If you desire, I can provide a more detailed field activity schedule to assist you in selecting a visit date.

I would like to say that the entire North Wind team is very excited to begin this Phase II project. Please let me know if I can provide any additional information. I can be reached at 609-714-3679 (office), 208-520-2419 (cell), or [jmartin@nwindenv.com](mailto:jmartin@nwindenv.com). You may also contact Kent Sorenson at 208-557-7829 (office), 208-520-5902 (cell), or [ksorenson@nwindenv.com](mailto:ksorenson@nwindenv.com). Thank you again for the opportunity to be of service.

Sincerely,

  
Jennifer P. Martin  
Scientist III

CC: w/attachments

Ken Logsdon	Kentucky DNREPC
Charles Taylor	USGS
Angie Allison	NW Boulder Office (3 copies)
Kent Sorenson	NW Idaho Falls Office
Patrick LeBow	NW Idaho Falls Office
Michael Koelsch	NW Idaho Falls Office
Neil Maimer	NW Idaho Falls Office





NWE-ID-2003-026  
Revision 0

# **Work Plan for Phase II Chitin/Fracing: Distler Brickyard Superfund Site, Hardin County, Kentucky**

*Angie M. S. Allison  
Jennifer P. Martin  
Kent S. Sorenson*

**April 2003**

NWE-ID-2003-026

**Work Plan for Phase II Chitin-Fracing:  
Distler Brickyard Superfund Site,  
Hardin County, Kentucky**

**Angie M. S. Allison  
Jennifer P. Martin  
Kent S. Sorenson**

**April 2003**

**Prepared for the  
National Science Foundation under Award No. DMI-0239859  
in cooperation with  
US EPA Region 4 and the State of Kentucky**

## ABSTRACT

This plan describes the activities of the Phase II field test of an innovative technology for the remediation of chlorinated solvent contamination in low permeability, variably saturated sediments. The selected technology, the chitin-fracing technology, combines the use of a hydraulic fracturing (fracing) technique with enhanced bioremediation through the creation of highly permeable sand- and electron donor-filled fractures in the low permeability matrix. In Phase I, a pilot-scale deployment was performed to determine if the selected approach was technically feasible. Upon successful completion of Phase I, the general approach for Phase II is to deploy the technology full-scale, specifically through the creation of a biologically active zone in the source area to cut off the flux of contaminants to the downgradient aquifer. Specific activities will include the installation of monitoring wells, emplacement of chitin-sand fractures, and groundwater monitoring from existing and newly installed wells. Analytes will consist of the primary contaminants and their degradation products, electron donors, oxidation-reduction indicators, geochemical indicators, water quality parameters, and water levels. These data will be used to evaluate 1) the longevity of chitin in the subsurface, and 2) the effectiveness of chitin as an electron donor under the changing water levels experienced by this system. This information will be used to further evaluate and maximize the performance and cost effectiveness of this technology.

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TOC	total organic carbon
USGS	United States Geological Survey
VC	vinyl chloride
VFA	volatile fatty acid
VOC	volatile organic compound

# **Work Plan for Phase II Chitin-Fracing: Distler Brickyard Superfund Site, Hardin County, Kentucky**

## **1. INTRODUCTION**

The Distler Brickyard Superfund Site is a former waste recycling facility located near the town of West Point, Kentucky. Waste storage activities at the Site have resulted in soil and groundwater that is contaminated with the chlorinated aliphatic hydrocarbons (CAHs) trichloroethene (TCE), 1,1,1-trichloroethane (1,1,1-TCA), and their degradation products. The presence of reducing conditions and less chlorinated degradation products cis-1,2-dichloroethene (cis-1,2-DCE), vinyl chloride (VC), and ethene indicates that biodegradation via anaerobic reductive dechlorination (ARD) was occurring naturally in the system. However, the rate and extent of ARD appeared to be limited by a lack of available electron donor. For this reason, a remediation technology that enhanced natural ARD via electron donor addition was hypothesized to be a viable method for reducing CAH concentrations to acceptable levels. The selected technology combines the use of a hydraulic fracturing (fracing) technique with enhanced bioremediation through the creation of highly permeable sand- and electron donor-filled fractures in the low permeability matrix. Chitin was selected as the electron donor because of its unique properties as a polymeric organic material and based on the results of lab studies that indicated its ability to support ARD.

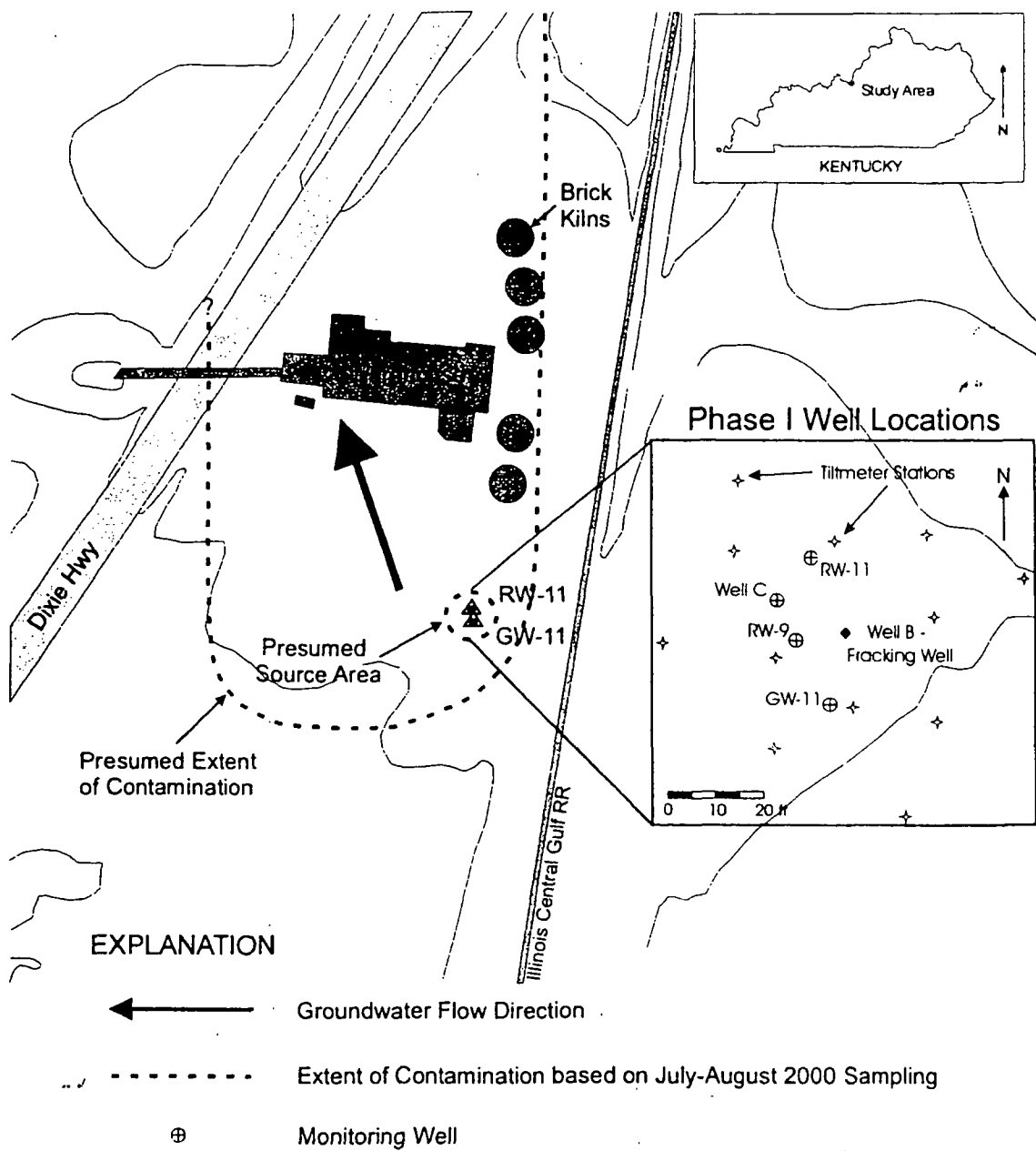
The development and application of the chitin-fracing technology is funded through the National Science Foundation (NSF) Small Business Innovation Research (SBIR) program. The first phase, Phase I, consisted of two sets of laboratory studies and a pilot scale field test at the Distler Brickyard Site. The pilot test was conducted October 2000 – January 2001. Based on the encouraging results obtained from Phase I, the project team submitted a proposal to NSF to support a Phase II deployment at the Distler Brickyard Site. This proposal was successful and Phase II activities are scheduled to begin in April 2003. This Work Plan provides the technical guidance for activities conducted during the execution of the Phase II project.

### **1.1 Site History**

The Distler Brickyard Site is located on unconsolidated alluvial and glacial outwash deposits along the Ohio River in northern Hardin County, Kentucky. The alluvium consists of two hydrostratigraphic units: the Fine Grained Alluvium (FGA) and the underlying Coarse Grained Alluvium (CGA). The FGA is approximately 12-m (40-ft) thick and consists of silty clay with sand and peat lenses. The CGA is composed of coarse sand and gravel. Its distribution may be controlled by the topography of the bedrock surface and is not present in the eastern portion of the Site. Where present, it ranges from 0.4- to 6-m (1.5- to 20-ft) thick (De la Pena 1989, Duffey et al. 1983). The FGA/CGA are underlain by silt and limestone bedrock at a depth of 12- to 18-m (40- to 60 ft) below ground surface.

The 28-ha (70-acre) site is a former brick manufacturing plant that was used as a waste recycling and storage facility between 1976 and 1979. During waste storage and recycling activities, drums of waste were stored aboveground. The sources of contamination at the Site were drums that spilled or leaked onto the soil surface and subsequently infiltrated to the water table (approximately 25 to 30 ft). Groundwater sampling during 1983 through 1985 indicated that groundwater in the vicinity of Monitoring Well GW-11 was the most highly contaminated at the Site. Analysis of data collected through 1985 identified a contaminant plume with the source area located near GW-11 (Anderson and Bomberger 1986) (Figure 1-1). The contaminants included CAHs (TCE, 1,1,1-TCA, and degradation products), monocyclic aromatic hydrocarbons (MAHs) (i.e., petroleum hydrocarbons), and ketones.





**Figure 1-1.** Distler Brickyard Site including the location of the Phase I test.

The U.S. Environmental Protection Agency (EPA) published a Record of Decision in 1986 specifying the following remedial action activities (EPA 1998):

- Excavation of contaminated soil
- Extraction and treatment of contaminated groundwater
- Operation and maintenance of a groundwater treatment system.

Excavation of 382 m<sup>3</sup> (500 yd<sup>3</sup>) of contaminated soil from the GW-11 area was completed in October 1988, and construction of the groundwater treatment system began in 1989 (OHM 1990). There is no documentation of soil removal from the area around GW-4, another potential source area. Analysis of data collected during operation of the groundwater treatment system indicated that most of the contaminants were located in the FGA, which because of its relatively low hydraulic conductivity (10<sup>-8</sup> to 10<sup>-4</sup> cm/s), exhibits low flow rates (EPA 1998). Due to the low hydraulic conductivity in the FGA, advective transport of contaminants through the FGA to the CGA is slow. Thus, removal of contaminants by groundwater extraction and treatment is not an effective remediation method for contaminants in the FGA.

## 1.2 Anaerobic Reductive Dechlorination

CAHs, such as TCE and 1,1,1-TCA, are relatively oxidized and are thus not readily susceptible to oxidative degradation. For this reason, they were believed to be non-biodegradable until degradation of PCE and TCE was observed in laboratory studies by Bouwer and McCarty (1983). The degradation mechanism was not oxidation but ARD. ARD of CAHs is the microbially mediated redox reaction in which chlorine atoms are sequentially removed and replaced with hydrogen atoms. Through this process, TCE and 1,1,1-TCA are degraded to ethene and ethane, non-toxic, non-chlorinated end products (Vogel et al. 1987).

In ARD, the CAH acts as an electron acceptor. An electron donor, in the form of natural organic matter or non-chlorinated organic compounds, must be present in order for ARD to proceed. In addition to an abundant supply of electron donor, competing electron acceptors (such as oxygen, nitrate, iron (III), and sulfate) must be absent. Electron acceptors that provide the most energy will be used preferentially by microorganisms. The order in which inorganic electron acceptors are typically utilized is: oxygen, nitrate, manganese (IV), iron (III), sulfate, and carbon dioxide. The optimum redox range for ARD is sulfate-reducing to methanogenic conditions. Therefore, in order for ARD of TCE and 1,1,1-TCA to be energetically favorable, competing electron acceptors must be absent, or electron donor must be present in sufficient concentrations to meet competing electron acceptor demand.

## 1.3 Chitin-Fracing Technology

Previous investigations (Anderson and Bomberger 1986; United States Geological Survey [USGS] in preparation; Martin et al. 2000) revealed evidence that suggested biodegradation (via ARD) of CAHs was occurring in the FGA. In summary, results of these previous investigations indicated that redox conditions in the FGA around GW-11 are favorable for reductive dechlorination, and an active dechlorination zone exists in this area. However, the presence of TCE downgradient in the CGA indicates that the extent of ARD is not sufficient to stop the flux of contaminants from the FGA and TCE migration from the GW-11 area downgradient to the CGA at concentrations slightly above the maximum contaminant level (MCL) (Martin et al. 2000). ARD in the FGA is likely limited by a lack of sufficient quantities of electron donor to drive the process. Downgradient in the CGA, conditions are aerobic and less chlorinated degradation products CA and VC are not present.

In order to address the relatively low concentrations of contaminants migrating to the CGA, a remedy that enhanced the ARD processes that were already occurring as described above was desired. The selected approach uses a solid phase electron donor (chitin) emplaced as a sand-slurry mixture into the formation using a hydraulic fracturing (fracing) technique called the FRAC RITE™ process. The FRAC RITE™ process, developed by FRAC RITE Environmental, Ltd. specifically for applications in unconsolidated, low permeability sediments, is conducted using down-hole proprietary fracturing equipment to create a network of highly permeable sand-filled fractures. In this particular application, chitin (JRW Technologies, Inc.) is incorporated with the sand in the fractures as an electron donor for ARD of CAHs.

The use of chitin at this site is an attractive approach because it is able to effectively address the constraints presented above. Once emplaced into the formation, the chitin is degraded slowly, producing a relatively long-lived source of nitrogen and electron donor in the form of volatile fatty acids (VFAs) for ARD. Chitin is effective under the variably saturated conditions of this unique system; significant concentrations of VFAs are released only when the chitin is saturated, the same conditions under which CAHs are mobilized and must be degraded. Under unsaturated conditions, VFA production is slowed, thus the electron donor is available only when necessary and the longevity of chitin in the subsurface is maximized. Finally, the use of chitin is also attractive due to its availability and cost. Chitin is the most plentiful natural biopolymer in the world next to cellulose and is available at a relatively low cost.

For these reasons, it was determined that the use of chitin-fracing technology for enhanced ARD of CAHs might be an effective remediation technology to address the unique constraints of this system. A pilot-scale deployment was designed and implemented to address the following specific objectives: 1) Determine whether chitin can be emplaced into a low permeability medium using the fracing technique, 2) Determine whether the fracing technique enhances the permeability of the formation, 3) Determine whether once emplaced, chitin produces significant concentrations of VFAs that impact redox conditions, and 4) Determine whether chitin enhances ARD of CAHs on a scale relevant to full-scale remediation.

## **1.4 Phase I Pilot Test Results**

The chitin-fracing technology is being evaluated through the NSF SBIR program. In this program, technologies are tested in two phases. Phase I of the SBIR program is a relatively short-term, limited scope test (6-month duration). Following the completion of Phase I and submittal of the final report, the opportunity is available to submit a Phase II proposal; Phase II is much larger in scope and duration (2-year duration). The Phase I evaluation of the chitin-fracing technology was conducted July 2001 – January 2002. The results of the Phase I test are summarized below; a complete description of the results is presented in Sorenson et al. (2002). The Phase II proposal was successful and funding was received in January 2003. The following section summarizes the results of the Phase I test.

The Phase I field test consisted of the creation of three chitin-filled fracture zones initiated from a single well (drilled during the fracing process) in the chlorinated solvent source area. The goals of the field test were to determine: 1) if the fracing enhanced the permeability of the formation, and 2) if chitin emplacement impacted the aquifer geochemistry such that conditions conducive for ARD of CAHs were created. Hydrologic monitoring, performed to address the first goal, consisted of tiltmeter monitoring, pre- and post-fracing slug tests, and a pumping test. Geochemical monitoring, performed to address the second goal, consisted of groundwater sampling in the fracing well and four surrounding monitoring wells. Groundwater sampling was conducted both prior to (baseline sampling) and monthly following chitin emplacement. The analytes consisted of electron donor parameters (chemical oxygen demand [COD] and the individual volatile fatty acids [VFAs]), redox parameters (nitrate, ferrous iron, sulfate, and methane), and ARD parameters (chloroethenes and ethene, and chloroethanes [CAHs] and ethane).

Results of hydrologic monitoring indicated that the fracturing produced a network of permeable fractures with a modeled effective radius of from 4 ft (uppermost frac) to 13 ft (two lower fracs). The pumping test showed that all four monitoring wells are in direct hydraulic connection with the fracturing well. Geochemical data indicate that chitin, where present, was able to affect the redox conditions and support enhanced ARD of chlorinated solvents. Where chitin was distributed (Well RW-9 area) redox conditions became more reducing and enhanced ARD was observed. Where chitin was not distributed (Well C area), redox conditions were not impacted and enhanced ARD was not observed. Further, monitoring conducted nine months following chitin emplacement indicated significant concentrations of VFAs remain in RW-9, and the presence of methanogenic conditions in four of the five pilot test wells. These results indicate that chitin is relatively long-lived in the subsurface and produces a long-term impact on the subsurface geochemistry. While additional full-scale studies are required, it appears that the chitin-fracturing technology can be a viable and cost-effective remediation technology for low permeability systems.

In summary, the Phase I pilot test produced the following conclusions:

- Chitin can be delivered effectively to the subsurface using the fracturing technique to distances of at least 13 ft in silts and clays.
- Chitin is degraded in situ to produce VFAs (mainly acetate) to support ARD of CAHs.
- After 9 months, significant concentrations of acetate and other VFAs persisted, indicating that chitin is a relatively long-lived electron donor.
- Where present, chitin created the methanogenic conditions required for complete ARD of TCE. These conditions persisted for at least 9 months following chitin emplacement.
- Where present, chitin enhanced the ARD of cis-1,2-DCE to ethene and these dechlorination reactions persisted for at least 9 months following chitin emplacement.
- Based on these results, chitin may be a cost-effective slow release electron donor, useful even in variably saturated environments.

## 2. OBJECTIVES

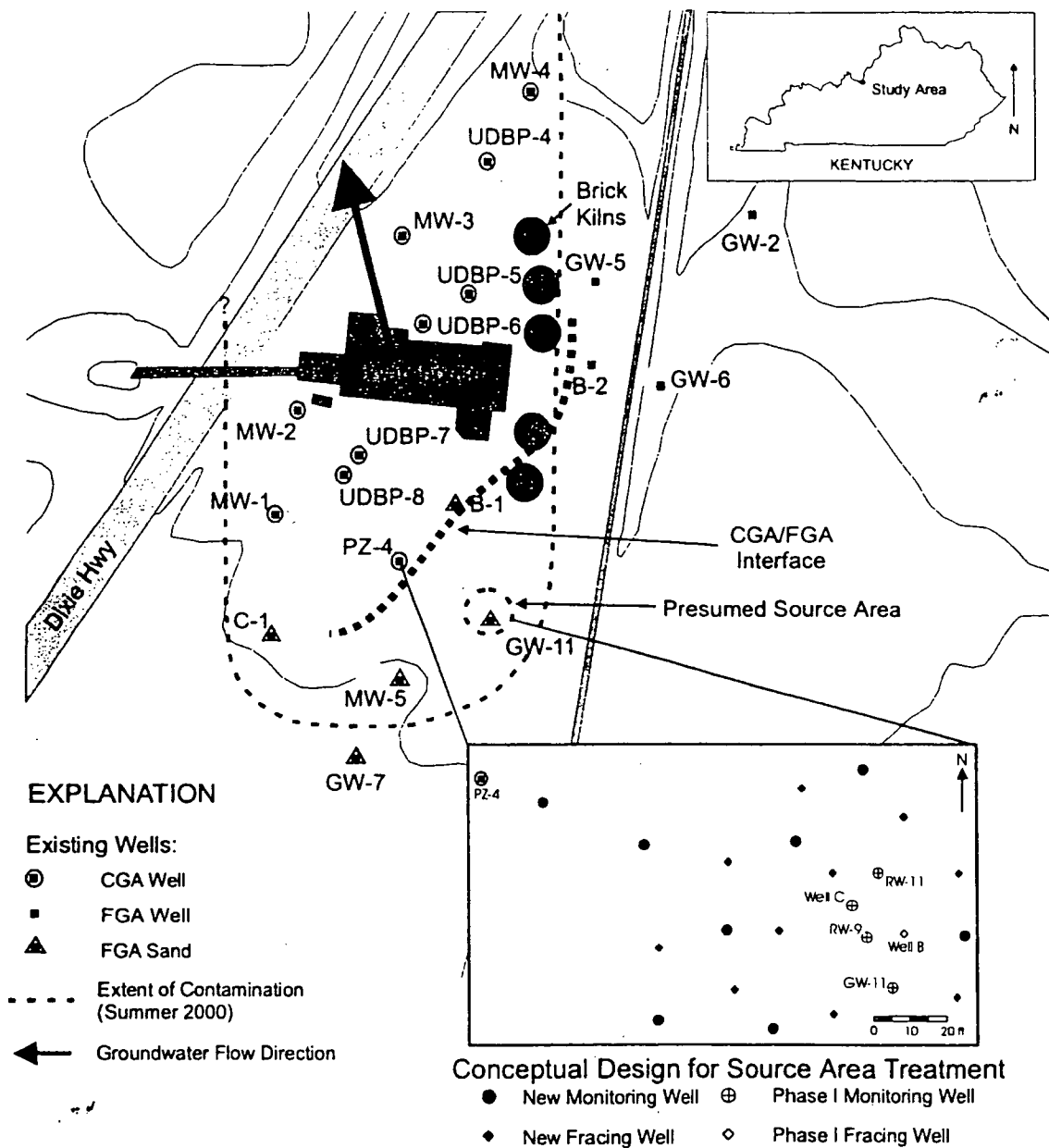
The Phase I project demonstrated the technical viability of the chitin-fracing technology for remediation of chlorinated solvents in low permeability, variably saturated soils. The primary objective of Phase II is to implement the technology to full-scale and to evaluate its overall technical- and cost-effectiveness.

The overall approach to meet these objectives is comprised of parallel field and laboratory efforts. The field effort will involve creating a biologically active zone in the source area, thus achieving complete ARD of chloroethene contaminants within this source and preventing downgradient migration of contaminants. To do this, additional fracing wells will be installed in the source area in the vicinity of "Well B", the Phase I fracing well, to distribute chitin throughout the approximate extent of the chlorinated solvent source area. A general design of the distribution of monitoring wells and chitin-fracing wells is provided in Figure 2-1. Both groundwater monitoring and analysis of soil cores over a nearly 2-year period will be used to evaluate the efficiency and longevity of the process.

The data from this field test will also be used to evaluate, and if possible improve, the commercial viability of the chitin-fracing technology. Two key issues related to the long-term performance and cost-effectiveness of the technology are chitin longevity and the performance of chitin under variably saturated conditions. The field test described here is 2 years in duration. This will provide ample time to evaluate the longevity of chitin in the subsurface. Based on the results of the Phase I pilot test, it is expected that the chitin will persist for a significant period of time, and a single emplacement may be sufficient to reduce contaminant concentrations to acceptable levels. However, if monitoring data indicate that the chitin has been depleted but contaminants are still present, the project team will make recommendations to EPA and the State of Kentucky for additional action.

The second issue is the performance of chitin under variably saturated conditions. Source contamination at the Distler Site is bound up in fine-grained sediments that undergo variable saturation in response to fluctuations in precipitation and recharge during seasonal changes. One of the benefits of chitin is that it is potentially effective under these variably saturated conditions. It is predicted that significant concentrations of VFAs are released only when the water levels rise and chitin is saturated, the same conditions under which contaminants are mobilized and degraded. Using the same logic, under unsaturated conditions, VFA production is slowed, thus the electron donor is available only when necessary and the longevity of chitin in the subsurface is maximized. This field test will provide data on the response and performance of chitin over almost two full seasonal cycles.

In addition to the field activities, laboratory studies will be used to provide key data related to the optimization of the technology. Details regarding laboratory studies were presented in the Phase II proposal and a short overview is provided here. The laboratory studies will focus on degradation efficiency under different chitin loading conditions and chitin longevity. The columns will be constructed with the same fracing sand used in the field as well as three different forms of chitin. The columns will be inoculated with a mixed microbial culture capable of complete dechlorination of TCE to ethene. Columns will be loaded with different mass ratios of chitin and sand for each type of chitin to try to optimize the cost of chitin in the context of its longevity and ability to facilitate complete dechlorination. This information can then be used to optimize the overall approach in terms of chitin cost, longevity, and performance, which will help maximize cost effectiveness.



**Figure 2-1.** Site map of the Distler Brickyard Superfund Site showing the extent of contamination and the conceptual design for the Phase II field test. Locations of the fracing and monitoring wells are approximate and subject to change to accommodate obstacles in the field. The Field Team Leader will determine final locations.

### 3. PHASE II FIELD ACTIVITIES

A field test was designed to meet the objectives described in Section 2. Additional fracturing wells will be installed throughout the source area to stimulate biodegradation. Additional monitoring wells will be installed to provide adequate monitoring locations throughout the treatment area. Groundwater monitoring will be conducted to monitor the impact of the chitin emplacement on the geochemical conditions and biodegradation. Finally, soil cores will be collected periodically to physically verify the distribution of fractures following fracturing and to evaluate any changes in the chitin within the fractures over time. The following sections provide the detail for each of these activities.

#### 3.1 Monitoring Well Installation

The proposed groundwater monitoring well locations are illustrated on Figure 2-1. Eight groundwater-monitoring wells will be installed using a 9620 Titan Powerprobe direct push system in accordance with the State of Kentucky regulations and permit requirements and the EPA Region 4 Standard Operating Procedure (SOP) (EPA 1996).

Each well location will be drilled to the top of bedrock, approximately 40 ft below ground surface (bgs), using 8 1/4 in. outside diameter (OD)/4 1/4 in. inside diameter hollow-stem auger. Each monitoring well will be constructed using 2-in. diameter, schedule-40 poly vinyl chloride (PVC) casing and 2-in. diameter, schedule-40 PVC .010-slot screen. All well materials will be installed inside the hollow stem auger. The Field Team Leader (FTL) will ensure that the filter pack and hydrated bentonite are added in sufficient quantity as to satisfy the well design (Appendix A).

Wellhead protection will be installed once the annular seal has settled and begins to set. The PVC riser will be cut to allow a stick-up of a minimum of 2.5 ft above the ground surface. An outer lockable, steel protective casing and a concrete well pad will be installed around each wellhead according to the EPA Region 4 SOP (EPA 1996). Three bollards will be installed around each wellhead. If wells are spaced closely enough, then fewer bollards can be used. This will be determined by the FTL in the field.

The well will be developed no sooner than 24 hours after the surface pad and outer protective casing have been installed. Before development, the FTL will record a static water level measurement. A well development pump will be used to develop each well according to EPA protocol (EPA 1996).

All drilling equipment will be thoroughly decontaminated by the drill crew between well boreholes to eliminate the risk of cross-borehole contamination, as described in Section 4.2.

#### 3.2 Fracing Well Installation

Additional fracturing wells will be installed in order to create a biologically active zone throughout the source area. The tasks required for the installation of this fracturing well network are described below.

##### 3.2.1 Subsurface Fracture Network Design

Based on the delineation of the presumed residual source area from previous investigative work conducted at the site, the lateral extent of the area appears to be confined within an area of approximately 100 × 100 ft in dimension (Figure 2-1). Nine additional fracturing wells will be placed in the source area at a spacing of approximately 30 ft using a 9620 Titan Powerprobe direct push system and the Frac-Rite proprietary fracturing tool. The approximate locations for the fracturing wells are presented in Figure 2-1.

To optimize the distribution of chitin in the subsurface and enhance the permeability of subsurface sediments, at least three fractures containing chitin slurry will be placed per fracing well. One fracture should ideally be initiated in each of the following zones at each fracing well: 1) the unsaturated zone (i.e., in the partially saturated zone immediately above the groundwater table); 2) slightly below the saturated zone-unsaturated zone boundary; and 3) the saturated zone. The depth to groundwater is approximately 30 ft bgs, near the sand-clayey silt contact, although water levels fluctuate seasonally.

The placement of individual chitin fractures at each fracture well location will be spaced at regular 5-ft vertical intervals in such a configuration that chitin is distributed throughout the entire solvent impacted sequence of sediments. Based on the Phase I work, fractures placed in the sediments at the Distler site will have an upward vertical component as they propagate radially from the well. Therefore, the following generalized fracture initiation depths will be used in each fracing well:

- Fracture 1 Initiation Depth: 28 ft below ground surface
- Fracture 2 Initiation Depth: 33 ft below ground surface
- Fracture 3 Initiation Depth: 38 ft below ground surface.

### **3.2.2 Fracture Slurry Composition**

The proposed full-scale fracture design is based on the design that was successfully employed during the Phase I pilot fracturing program. The components of the fracture slurry include:

1. Fracture base gel: water based, guar-derivative organic polymer.
2. Fracture sand: American Petroleum Institute (API) spec silica frac sand of 20-40 US Mesh grain size and 98% sphericity and silica content.
3. Chitin: 20-40 US Mesh particle size.
4. Fracture slurry: mix of fracture base gel, fracture sand, and chitin to a final concentration of 1:4 chitin to sand.
5. Fracture slurry volume: target volume of 265 gal (one cubic meter) per fracture.

### **3.2.3 Chitin Fracture Network Placement and Mapping**

Tiltmeter monitoring and modeling is a technique used to map the subsurface propagation of fractures from the fracing well. This technique will be used on a subset of wells, selected by the FTL in the field, during the fracing activity. Prior to fracturing, all proposed fracing well locations will be staked so that a constant well spacing of about 30 ft is maintained. Before fracturing commences at each of the fracing well locations, an array of surface mounted tiltmeter stations will be set up on a concentric grid around the fracing well. During the fracturing process, the tiltmeters will record the micro-movements in the ground surface in response to fracturing. These data are stored in data loggers for subsequent geophysical analysis of fracture geometry.



### 3.2.4 Hydraulic Fracturing and Well Completion

While the tiltmeter array is placed, the fracture slurry will be prepared and the appropriate chitin:sand ratio incorporated into the fluid. Also at this time, the borehole will be pre-drilled using the PowerProbe to approximately 10 ft above the first fracture in preparation for advancing the Frac-Rite proprietary fracing tool to the first designated fracture depth, whereupon the fracture slurry will be pumped under hydraulic pressure to initiate and propagate a radial fracture from this depth. As described above, the anticipated volume of fracture slurry to be pumped is one cubic meter per frac (approximately 265 gal) for a theoretical fracture radius of approximately 12 to 15 ft.

After the first fracture has been pumped to completion, a new batch of frac fluid will be formulated. Once it has been prepared, the procedure is repeated. The bottom-most fracture will be initiated and propagated in the same manner as the first two fractures. Once all of the fractures have been placed, the frac tool assembly is raised out of the borehole. All fractured boreholes will be completed as monitoring wells after fracing is complete using the PowerProbe. All wells will be built using the same basic well design as the groundwater monitoring wells (Appendix A). The FTL will ensure that each well is screened from no less than 2 ft above the shallowest frac to the bottom of the well.

## 3.3 Soil Coring

The objective of the Phase II soil-coring program is to determine the distribution of fractures visually for comparison to the geophysical (tiltmeter) analysis and to document visual changes to the chitin found in the fractures over time. The approach will be to collect several complete cores to bedrock within the fracture network at four different time points during the project. Core locations will be selected in the field by the FTL.

The first coring event will occur immediately after the fracing is completed. Three subsequent coring events will be performed approximately each 6 months thereafter (Appendix B). This will enable visual changes in the chitin to be documented over the nearly 2-year project duration. These changes will provide insight into the longevity of chitin in the field for comparison to the laboratory tests. It will also enable a thorough map of the fracture network to be created to determine the effectiveness of chitin distribution and to evaluate the accuracy of the geophysical modeling of fracture propagation based on the tiltmeter data.

Approximately six soil cores will be collected during each sampling event using the PowerProbe 9620 direct push sampling system to bedrock, approximately 40 ft bgs. Continuous core will be collected in 1/8-in. x 4-ft long clear acetate liners. Each core will be visually inspected by the field team to determine the distribution of sand- and chitin-filled fractures, and logged. Soil cores may also be sent to Dr. Rachel Brennan at Pennsylvania State University for laboratory analysis. Cores shipped off-site will be sealed with end caps and duct tape. The FTL will determine which, if any, soil cores will be sent offsite.

All drilling equipment will be thoroughly decontaminated by the drill crew between soil core locations, as described in Section 4.2, to eliminate the risk of cross-borehole contamination.

### **3.4 Groundwater Monitoring**

The objective of the Phase II groundwater monitoring program is to evaluate the efficiency and longevity of chitin-stimulated biodegradation of chlorinated solvents in a full-scale application. Parameters to be monitored include water levels, VFAs produced by chitin, redox indicators (nitrate, iron, sulfate, and methane), and contaminants and degradation products (chloroethenes, ethene, chloroethanes, and ethane). As during Phase I, ferrous iron, nitrate, and alkalinity will be analyzed using standard field test kits. The volatile organic compounds and dissolved gases (ethene, ethane, and methane) and sulfate will be analyzed at the EPA Region 4 Laboratory, located in Athens, GA. The VFAs will be analyzed at Penn State University.

#### **3.4.1 Sampling Location and Frequency**

Monitoring wells located within the network of fracing wells will be sampled as well as selected downgradient wells completed in the CGA. In addition, the USGS performs quarterly monitoring at a subset of site wells. Data from this USGS monitoring will be incorporated into the data analysis for the Phase II test as they are available. The former will facilitate evaluation of the impact of the fracture network on conditions in the FGA, while the latter will allow assessment of the extent to which the chitin stimulates sufficient biodegradation to stop the flux of contaminants from the presumed source area in the FGA to the CGA. Sampling and Analysis (SAP) tables are created to guide the sampling events. Appendix B provides the SAP tables for the baseline and first post-fracing sampling rounds; additional tables will be created for each sampling event prior to the scheduled sampling dates.

A baseline-monitoring round will be conducted prior to chitin-fracing. Groundwater samples will be collected from existing wells RW-9, UDBP-8, PZ-4, MW-3, and the eight newly installed monitoring wells (Figure 2-1). Additional wells will be sampled as time and materials permit at the discretion of the FTL.

The monitoring frequency after the chitin-fracing will be monthly for six months, decreasing to bimonthly for the remainder of the two-year study. Groundwater samples will be collected from RW-9, UDBP-8, PZ-4, MW-3, and the eight newly installed monitoring wells (Figure 2-1). Additional wells will be sampled as time and materials permit at the discretion of the FTL. The first monthly sampling event will occur the week following the fracing event.

This monitoring program will provide data sufficient to capture any rapid changes in geochemistry and contaminant concentrations following chitin emplacement, as well as document long-term changes. It will also cover almost two complete seasonal cycles, which have been documented to affect contaminant flux and redox conditions at this site. Thus, the benefit of injecting chitin in the seasonally saturated portion of the formation can be evaluated.

Analytical samples for laboratory analyses will be collected in pre-cleaned bottles and packaged according to EPA procedures (EPA 1996) and as outlined in Section 4 of this document. The quality assurance/quality control (QA/QC) samples, as described in Section 7, will be included to satisfy the QA/QC requirements for the field operation, in accordance with appropriate EPA procedures (EPA 1996).

## 4. SAMPLE COLLECTION PROCEDURES

All sampling activities will be performed in accordance with the EPA Region 4 SOP (EPA 1996). The following subsections describe the sample collection procedures to be used for the planned groundwater sampling and analyses described in this Work Plan. Prior to the commencement of any sampling activities, a pre-sampling meeting will be held to review the requirements of the Work Plan and to ensure all supporting documentation has been completed.

### 4.1 Groundwater Sampling

#### 4.1.1 Purging

Wells will be purged using a submersible pump to remove stagnant water from the monitoring well before sampling. Prior to initiating the purge, new plastic sheeting will be placed on the ground surface around the well casing to prevent contamination of the pump, hose, etc., in the event they accidentally come into contact with the ground surface. In addition, the amount of water standing in the well will be determined prior to purging.

The following procedure outlines the purging procedure that will be used at the Site according to EPA protocol (EPA 1996):

1. Depth to groundwater will be measured immediately prior to purging the well. A well volume will be calculated using the following equation:

$$V = 0.041d^2h$$

where

h = depth of water in feet

d = diameter of well in inches

V = volume of water in gallons.

2. At a minimum, three well volumes will be purged using a submersible pump. Specific conductance, pH, and temperature will be measured during this time. Stabilization occurs when specific conductance and temperature vary by no more than 10 percent and pH varies by no more than 0.1 Standard Units (SU) for at least three consecutive readings.
3. If after three well volumes parameters have not stabilized, then additional well volumes can be purged. If after five well volumes parameters have not stabilized, additional well volumes can be purged at the discretion of the FTL.

Previous monitoring at this Site has indicated that wells in the FGA have relatively low recharge rates. Because of the relatively low transmissivity of the FGA, this rate of recharge is usually not sufficient to sustain prolonged pumping and some wells can be pumped dry before three well volumes are purged and parameters have stabilized. Therefore, a modified purging procedure consistent with EPA guidelines has been developed that has proven effective for the conditions present at the Distler Site. If during purging a well is dewatered, by definition the recharging water comes from the surrounding formation (i.e., the stagnant borehole water has been removed). In this case, the well will be allowed to recover sufficiently to allow adequate volume for sampling.

#### 4.1.2 Sampling

Sampling will be conducted to obtain, containerize, and preserve the ground-water sample after the purging process is complete. The plastic sheeting will remain on the ground around each well to provide a clean working area. A nylon rope will be attached to a closed-top disposable Teflon® bailer. For each sample location, a new disposable Teflon® bailer with a new nylon rope will be used.

The bailer will be gently immersed in the top of the water column until just filled. At this point, the bailer will be carefully removed and the contents carefully poured from the top of the bailer into each sample container. For collection of volatile organic compounds (VOCs) and ethene/ethane/methane samples, three 40 mL amber glass vials (for each analysis) with Teflon®-septum caps will be completely filled to prevent volatilization, and extreme caution will be exercised to avoid any turbulence, which could also produce volatilization. Prior to sample collection, the appropriate preservative will be added to the VOC, VFA, and ethene/ethane/methane sample containers. The volume of preservative to achieve the required pH (<2) will be determined with groundwater from each well prior to sample collection. The water will then be carefully poured down the side of the vial, and the last few drops will be gently poured into the vial so that surface tension holds the water in a convex meniscus. The cap will then be applied. After capping, the vial will be turned over and tapped to ensure the absence of air bubbles. If air bubbles are present, the procedure will be repeated with a clean vial.

The specific conductance, temperature, and pH will be measured during sample collection as the measurements of record for the sampling event.

#### 4.1.3 Filtering

Samples collected for VFA analysis require field filtration prior to collection. Samples will be filtered in the field using 0.2- $\mu$ m disposable membrane filters. Samples collected for nitrate and ferrous iron analyses may be filtered prior to analysis depending on the turbidity of the groundwater. As these are colorimetric analyses, turbid groundwater may cause an interference with the analysis. For this reason, the turbidity of the groundwater will be evaluated upon collection and samples will be filtered, if necessary, using a 0.45- $\mu$ m disposable membrane filter. The need for filtering will be determined by the FTL upon visual inspection of the sample.

### 4.2 Decontamination

Field decontamination procedures are designed to prevent cross-contamination between locations and samples and prevent the transmittal of contamination off-site via contaminated equipment. All equipment associated with purging and sampling (pump, tubing, specific conductance/temperature probe, and field sample containers) will be thoroughly decontaminated prior to daily activities and between sample locations.

The following procedure will be used to decontaminate the pump and tubing:

- The pump will be removed from the well and the tubing will be laid out on plastic sheeting.
- Approximately 4 gal of soapy tap water will be pumped through the tubing.
- The pump and tubing exterior will be scrubbed using a brush in a basin of tap water and phosphate-free laboratory detergent.

- A sufficient amount of clean water will be pumped through the tubing to flush out all of the soapy water. Care will be taken to ensure that the tubing does not touch the ground (plastic sheeting may be used to prevent the tubing from touching the ground surface).
- A second volume of clean water will be pumped through the tubing.
- The exterior of the pump and tubing will then be rinsed with de-ionized water and lowered into the next well.
- In-between sampling events, the pump and tubing will be covered in plastic to prevent contamination while in storage. All equipment cleaned and wrapped for field use will be marked with the date on which preparation was completed.

The field instrumentation equipment will be cleaned using a laboratory-grade detergent followed by a triple rinse in de-ionized water. Following decontamination, equipment will be wrapped in plastic or foil to prevent contamination from windblown dust. All equipment cleaned and wrapped for field use will be marked with the date on which preparation was completed.

## **5. SAMPLE HANDLING, PACKAGING, AND TRANSPORTATION**

### **5.1 Sample Handling and Analysis**

After collection, all sample handling will be minimized. Due to the sensitivity of the iron (II), nitrate, and alkalinity analyses, these parameters will be analyzed in the field immediately upon sample collection using field test kit methods. Water quality indicators (temperature, specific conductance, and pH) will be measured with a multi-probe instrument.

Samples collected for VFA analysis will be filtered, as discussed in Section 4.2, immediately after collection. All other samples will be unfiltered unless the groundwater is excessively turbid. In this case, samples for colorimetric analyses (iron [II] and nitrate) will be filtered in the field prior to analysis.

#### **5.1.1 Sample Containers**

Table 5-1 includes the identification of the container volumes, types, holding times, and preservative requirements that apply to the samples being collected under this Work Plan. Sample containers will be obtained from an approved retail source in sealed boxes and will be verified as pre-cleaned using the appropriate EPA-recommended cleaning protocols for the bottle type and sample analyses. Extra containers will be available in case of breakage, contamination, or if additional samples are collected. Prior to use, labels with the name of the project, sample identification number, location, and requested analysis will be affixed to the sample containers. Sample designation criteria are described in Section 6.

#### **5.1.2 Sample Preservation**

Samples for some analyses must be preserved in order to maintain their integrity. All samples collected will be preserved according to EPA protocols (EPA 1996).

Preservation of groundwater and water samples (except VOCs, VFA, and ethene/ethane/methane samples) will be performed immediately upon sample collection using the preservatives indicated in Table 5-1. VOC and ethene/ethane/methane samples will be preserved prior to sample collection to minimize the loss of volatiles. The volume of preservative necessary to achieve the required pH change (to a value of <2) will be determined in the field for each individual well prior to collection of the VOC and ethene/ethane/methane samples. This procedure will account for any differences in the geochemistry between wells and ensure that preservation requirements are met. Samples will be kept cool in ice chests (coolers) containing frozen ice. The temperature will be checked periodically prior to shipment to certify adequate preservation for those requiring temperatures at 4°C (39°F) for preservation.

#### **5.1.3 Personal Protective Equipment**

The personal protective equipment (PPE) required for any drilling activities, including well installation and soil core collection, is Modified Level D (hard hat, nitrile gloves, steel toe boots, and eye protection). PPE required for groundwater sampling includes steel toe boots, nitrile gloves and eye protection.

**Table 5-1.** Sample volume, preservation, and holding time.

Analyte	Container	Preservation	Holding Time (days)
VOCs (U.S. EPA Athens Lab)	3 - 40 mL glass VOA vials (Teflon septum lid)	HCl (50%) to pH<2, Cool 4°C±2	14 <sup>1</sup>
Ethene/ethane/methane (U.S. EPA Athens Lab)	3 - 40 mL glass VOA vials (Teflon septum lid)	HCl (50%) to pH<2, Cool 4°C±2	14 <sup>1</sup>
Volatile Fatty Acids (Penn State University)	1 - 40 mL glass VOA vials (Teflon septum lid)	H <sub>2</sub> SO (50%) to pH<2, Cool 4°C±2, Filter on-site (0.2 µm)	7
Iron (II) (Field Test Kit)	125 mL Polyethylene	None Filter if necessary (0.45 µm)	Analyze Immediately On-Site
Nitrate (Field Test Kit)	125 mL Polyethylene	None Filter if necessary (0.45 µm)	Analyze Immediately On-Site
Sulfate (U.S. EPA Athens Lab)	1 L Polyethylene	Cool 4°C±2	28
Alkalinity (Field Test Kit)	250 mL Polyethylene	Cool 4°C±2	14 (Analyze On-Site)
Microbiological Analyses (Penn State University)	2 - 1 L Amber Glass	Cool 4°C±2	NA
Temperature/pH/Specific Conductance (Field Measurements)	250 mL Polyethylene	None	Analyze Immediately On-site

<sup>1</sup> 14 days to TCLP extraction, 7 days to solvent extraction, 40 days to analysis

## 5.2 Packaging and Transportation

All samples will be packaged and transported according to EPA protocol (EPA 1996).

Samples will be transported each Thursday of the sampling weeks to the EPA Water Quality Laboratory in Athens, Georgia, and to Penn State University, as applicable, in accordance with the regulations issued by the DOT (49 CFR Parts 171 through 178) and EPA sample handling, packaging, and shipping methods (40 CFR 262). The person offering such material for transportation is responsible for ensuring such compliance. An overnight express carrier will typically ship the sample coolers to the laboratory. A copy of the bill of lading (air bill), if applicable, will be retained for the project file.

The laboratory will be notified 2 weeks in advance of all shipments, preferably by advanced scheduling, and by telephone on the day of shipment. Notification to the laboratory will include: the date of the shipment; name of shipping company, if applicable; bill of lading (air bill) number, if applicable; number of coolers; name, phone number, and facsimile number of point of contact; estimated date of shipment arrival; and type of samples.

## **5.3 Documentation**

The FTL will be responsible for controlling and maintaining all field documents and records. Sample documentation procedures for this project are based on EPA-recommended procedures that emphasize careful documentation of sample collection and sample transfer.

All information recorded on project documentation will be made in permanent ink. All errors will be corrected by drawing a single line through the error and entering the correct information; all corrections will be initialed and dated. All original documents relating to this project will be placed in the project file. This includes, but is not limited to, the following documents:

- Work Plan
- Chain-of-custody records
- Field logbook
- Complete copy of the analytical data.

The project leader shall review the file at the conclusion of the project to ensure that it is complete.

### **5.3.1 Sample Container Labels**

Waterproof, gummed labels will be applied to sample containers that will be submitted to an analytical laboratory. These labels will not be capable of being removed without leaving obvious indications of the attempt. Labels will not be placed over previously recorded information.

The label information will be completed in the field and placed on the containers before collecting the sample. The following information will be included on the sample label: sample identification (ID) number, the name of the project, the sampling location, date and time of sample collection, the preservative used (if applicable), requested analysis type, and the signature of either the sampler(s) or the designated sampling team leader.

Samples collected for specific field analyses or measurement data (i.e., specific conductance, temperature, and pH) are recorded directly in bound field logbooks or recorded directly on the chain-of-custody record, with identifying information, while in the custody of the samplers.

### **5.3.2 Field Logbooks**

A field logbook dedicated to this project will be used to record information necessary to interpret the analytical data. The field personnel, the project name and location, and the project number should be entered on the inside of the front cover of the logbook. The information to be recorded in the logbook includes the sample collection equipment, field measurement and analytical equipment, water level measurements, calculations (including the well volume determinations), purge times and volumes, results, and calibration data for field sampling, field analytical, and field physical measurement equipment, time of sample collection, description of sample location, description of the sample, identification of sampler, sample collection methods, and weather conditions that may affect the sample. The logbook will be signed and dated at the end of each day's sampling activities.



### **5.3.3 Chain-of-Custody Procedures**

Samples will be collected, transported, and received under strict chain of custody protocols consistent with procedures established in the EPA Region 4 SOP (EPA 1996).

Adequate sample custody will be achieved by means of appropriate field and analytical laboratory documentation. A chain-of-custody form will be completed and will accompany each shipment of samples to the laboratory to establish the documentation necessary to trace sample possession from time of collection. The form will contain the sample ID number, the name of the project, the project number, the sample collection type designation, the signature of collector, sampler, or recorder, the date and time of collection, the place of collection, the sample type, the analysis requested, signatures of persons involved in chain of possession, and inclusive dates of possession. A brief description of the type of sample and/or the sampling location must be included on each line.

When transferring the samples, the individuals relinquishing and receiving the samples will sign, date, and note the time on the chain-of-custody form. The field team will retain a copy of the chain-of-custody form for the project files.

## 6. SAMPLE DESIGNATION

The SAP table was developed to simplify the presentation of the sampling scheme for project personnel. This table, which is presented in Appendix B, outlines individual sample characteristics, exact sample locations, and analytical types. Appendix B contains tables for the first two groundwater monitoring events, as well as the first soil coring event. Additional tables will be prepared prior to subsequent sampling events throughout the execution of the project.

A systematic character ID code will be used to uniquely identify all samples. Uniqueness is required for maintaining consistency and preventing the same ID code from being assigned to more than one sample. For primary and duplicate groundwater samples, the first four designators of the sample ID code refer to the well from which the sample was obtained. For QA/QC samples, the first two designators refer to the project site and the next two designators refer to the type of QA/QC sample. The next six designators refer to the month, day, and year in which the sample was collected. The next two numbers differentiate between a primary sample (01) and a field duplicate sample (02). The next two numbers designate the sequential sample number for the well location. The last two characters refer to a particular analysis type. Refer to the SAP table in Appendix B for specific analysis type code designations.

For soil cores, the first two designators will be "SC" for soil core. The next two designators refer to the soil core location. The final two numbers are the sample depth interval.

## 7. QUALITY

The quality assurance objectives specify the analytical requirements that data must meet in order to satisfy project objectives. Quality assurance and control measures to be followed during the collection of groundwater samples are specified in the EPA Region 4 SOP and QA Manual (EPA 1996).

### 7.1 Quality Assurance/Quality Control Samples

The QA/QC samples required for this project are summarized in Table 7-1.

**Table 7-1.** Quality assurance samples.

QA/QC Sample Type	Frequency
Duplicate	10% of total samples
Trip Blank	1 per day that VOC samples are collected
Field Blank	2.5% of total samples
Equipment Field Blank	5% of total samples

#### 7.1.1 Duplicate Samples

Duplicate samples are two or more samples collected from a common source. Duplicate samples will be collected at a frequency of 10% of the total samples per sampling event, and the distribution of duplicate samples may be placed at the discretion of field personnel with the concurrence of the Project Manager. Duplicate samples will be collected during each sampling event and will be analyzed for all analytical methods for which the primary sample is analyzed.

#### 7.1.2 Equipment Field Blank Samples

Equipment Field Blanks are the final analyte-free rinse water collected following decontamination of dedicated sampling equipment during a sampling event. After the field sample containers have been field cleaned and prior to their being used for sample operations, they will be rinsed with organic/analyte-free water. Equipment field blanks will be collected at a frequency of 5% of the total samples per sampling event to check the efficiency of decontamination and to ensure that no cross-contamination has occurred. The equipment field blank samples will be analyzed for all analytical methods for which the primary samples are analyzed.

#### 7.1.3 Field Blanks

Field blanks are collected and analyzed to determine the level of contamination, if any, introduced into the sample during field sampling activities. Field blanks should be collected in dusty environments and/or from areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled (EPA 1996). As it is difficult to quantify whether or not a site qualifies as 'dusty' and VOC vapors from automobiles are ubiquitous, field blanks will be collected. Analyte-free water will be taken to the field in sealed containers, and will be poured into the appropriate sample containers at pre-designated locations at the site. Field blanks will be collected at a frequency of 2.5% of the total samples per sampling event.

#### **7.1.4 Trip Blank**

A trip blank is required for every study where water samples are collected for VOC analysis. A minimum of one sealed preserved (or unpreserved if appropriate) 40-mL VOC vial will be transported to the field per day that VOC samples are collected. These trip blanks will be handled and treated in the same manner as the water samples collected for VOC analysis.

## **8. WASTE MANAGEMENT**

The waste streams that will be generated because of sampling activities include purge water, non-hazardous test kit waste, hazardous test kit waste, PPE, solid sanitary waste, samples, and decontamination water.

### **8.1.1 Purge Water**

The method of purge water disposal for this site, as documented in USGS (2002), is to the ground not less than 5 ft away from the sampled wellhead. This is based on the fact that the purge water at the Distler Site typically contains low levels of VOC contaminants, generally ranging from 1 to 100 µg/L, and purge volumes are very small – generally only 5 to 15 gal of water, a volume which will be readily absorbed by soil or vegetation or lost to evaporation (USGS 2002).

### **8.1.2 Non-Hazardous Test Kit Waste**

Approximately two liters of non-hazardous liquid waste will be generated from the iron (II) and alkalinity field test kits during each sample event. This liquid waste can be disposed of in the source area from which it originated, downgradient of the groundwater monitoring well.

### **8.1.3 Hazardous Test Kit Waste**

Hazardous waste must be disposed as specified in EPA regulations. Approximately one liter of hazardous (according to the manufacturer) liquid waste will be generated from the nitrate field test kit during each sample event. Based on process knowledge, the Resource Conservation and Recovery Act (RCRA) hazardous waste code is D006 for cadmium. This waste will be incorporated into a pre-existing waste stream at the USGS. Care will be taken to keep non-hazardous materials segregated from hazardous materials.

### **8.1.4 Personal Protective Equipment and Solid Sanitary Wastes**

PPE requiring disposal will include gloves and tyvek. Solid sanitary waste requiring disposal includes all paper, packaging, absorbent towels, used bailers, plastic sheeting, filters, and other miscellaneous waste generated during sample preparation and packaging that has not been contaminated. This type of waste will be placed in 208 L (55-gal) trash bags. Since contaminant levels at this site are relatively low, it is highly unlikely that materials coming into contact with groundwater would exhibit a RCRA characteristic for hazardous waste (i.e., corrosivity or ignitability). Also, groundwater at the site is not a RCRA-listed waste. Therefore, all PPE and solid sanitary waste will be disposed of in a facility dumpster.

### **8.1.5 Samples**

The analytical laboratories will be required to dispose of all samples and any waste generated as a result of analyzing the samples.

### **8.1.6 Decontamination Water**

Decontamination water may contain negligible concentrations of contaminants. Using the same logic presented for the purge water, all decontamination water will be discharged directly to the ground (USGS 2002).

## 9. PROJECT ORGANIZATION AND SCHEDULE

Table 9-1 presents contact information for key personnel involved in the execution of this project.

**Table 9-1.** Project organization.

<b>Title</b>	<b>Personnel</b>	<b>Organization</b>	<b>Contact Information</b>
EPA Remedial Project Manager	Femi Akindele	USEPA Region 4	Atlanta, GA (404) 562-8809
Kentucky NREPC Project Manager	Ken Logsdon	Kentucky NREPC	Frankfort, KY (502) 564-6716
EPA Analytical Laboratory Contact	Nardina Turner	USEPA Region 4 Sample Control	Atlanta, GA (404) 562-8809
USGS Contact	Chuck Taylor	USGS	Louisville, KY (502) 493-1931
NW Project Manager	Kent Sorenson	North Wind, Inc.	Idaho Falls, ID (208) 557-7829
NW Field Team Leader	Jennifer Martin	North Wind, Inc.	Medford, NJ (609) 714-3679
Frac-Rite Collaborator	Gordon Bures	Frac-Rite Env. Ltd.	Calgary, Alberta, Canada (403) 265-5533
PSU Collaborators	Jay Regan and Rachel Brennan	Penn State University	University Park, PA (217) 333-7039 (before June 03) (814) 865-9436 (after June 03)

The Phase II work began with the design and planning activities in March 2003. Field activities will begin around April 14, 2003. Table 9-2 provides the general schedule for completion of Phase II activities.

**Table 9-2. Schedule of activities for Phase II.**

<b>Activity</b>	<b>Scheduled Duration</b>
<b>Field Activities</b>	
• Monitoring Well Installation and Well Development	April 14-April 20, 2003
• Baseline Sampling	April 21-April 26, 2003
• Chitin-Fracing	April 27-May 5, 2003
• Soil Coring #1/Monthly Groundwater Sampling #1	May 6-May 10, 2003
• Monthly Groundwater Sampling #2	June 2003
• Monthly Groundwater Sampling #3	July 2003
• Monthly Groundwater Sampling #4	August 2003
• Monthly Groundwater Sampling #5	September 2003
• Soil Coring #2/Bimonthly Groundwater Sampling	November 2003
• Bimonthly Groundwater Sampling	January 2004
• Bimonthly Groundwater Sampling	March 2004
• Soil Coring #3/Bimonthly Groundwater Sampling	May 2004
• Bimonthly Groundwater Sampling	July 2004
• Bimonthly Groundwater Sampling	September 2004
• Soil Coring #4/Bimonthly Groundwater Sampling	November 2004
<b>Laboratory Studies</b>	January 2004 – December 2004
<b>Data Analysis</b>	June 2003 – January 2005
<b>Final Report</b>	January 2005 – March 2005

## 10. REFERENCES

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- 49 CFR 171, 2002, Title 49, "Transportation," Part 171, "General Information, Regulations, and Definitions," *Code of Federal Regulations*, Office of the Federal Register.
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- 49 CFR 177, 2002, Title 49, "Transportation," Part 177, "Carriage by Public Highway," *Code of Federal Regulations*, Office of the Federal Register.
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- Sorenson, K. S., Martin, J. P., Brennan, R. A., Bures, G. H., Werth, C. J., and Sanford, R. A., 2002, *Phase I SBIR Final Report: Development of a Chitin-Fracing Technology for Remediation of Chlorinated Solvent Source Areas in Low Permeability Media*.
- USGS, in preparation, *Investigation of Trends in Volatile Organic Chemicals in Ground Water at the Former Distler Brickyard Superfund Site*, Hardin County, Kentucky, 1995-1997, USGS Water Resources Division Draft Report.
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# **Appendix A**

## **Well Completion Schematic**

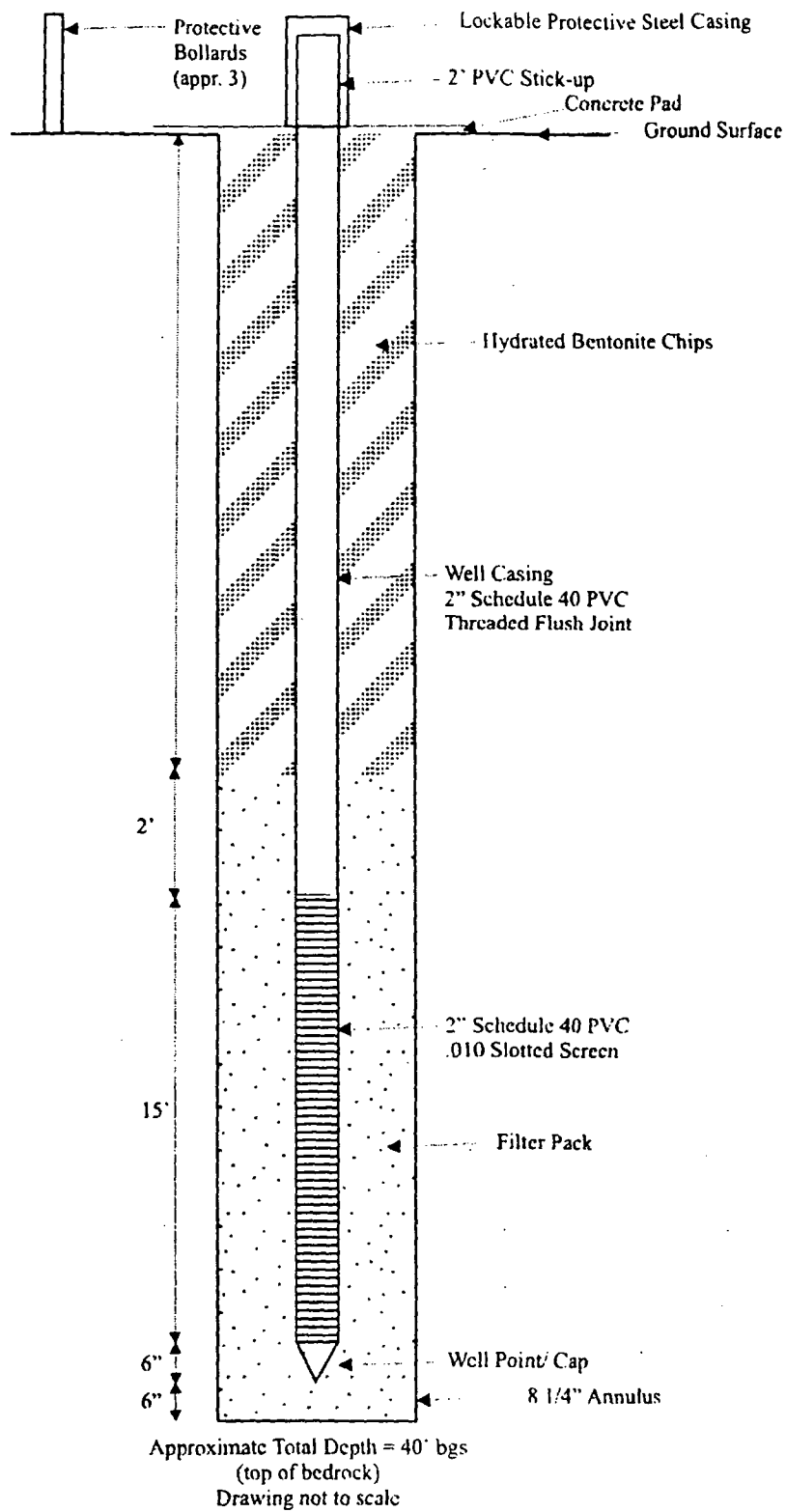


Figure A-1. Well Design for Groundwater Monitoring and Fracing Wells

**Appendix B**  
**Sampling and Analysis Plan Tables**

**Baseline Groundwater Sampling**

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Grab	Groundwater	Bailer/ Pump	April 2003	RW-9	Monitoring Well	Approx. 30 feet bgs	RW9-04XX03-01-01- (Analysis Type) Note: "Analysis Type" codes are located in the next column)	VOCs (VOC), Ethene/ ethane/ methane (EEM), VFAs (VFA), Iron II (FE), Nitrate (NI), Sulfate (SU), Alkalinity (AL), Microbiological Analyses (MA)
Grab	Groundwater	Bailer/ Pump	April 2003	UDBP-8	Monitoring Well	Approx. 30 feet bgs	UDBP8-04XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	PZ-4	Monitoring Well	Approx. 30 feet bgs	PZ4-04XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	MW-3	Monitoring Well	Approx. 30 feet bgs	MW3-04XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	New MW-10	Monitoring Well	Approx. 30 feet bgs	MW10-04XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	New MW-11	Monitoring Well	Approx. 30 feet bgs	MW11-04XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	New MW-12	Monitoring Well	Approx. 30 feet bgs	MW12-04XX03-01-01- (Analysis Type)	As above

# **Baseline Groundwater Sampling**

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Grab	Groundwater	Bailer/ Pump	April 2003	New MW-13	Monitoring Well	Approx. 30 feet bgs	MW13-04XX03-01- 01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	New MW-14	Monitoring Well	Approx. 30 feet bgs	MW14-04XX03-01- 01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	New MW-15	Monitoring Well	Approx. 30 feet bgs	MW15-04XX03-01- 01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	New MW-16	Monitoring Well	Approx. 30 feet bgs	MW16-04XX03-01- 01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	New MW-17	Monitoring Well	Approx. 30 feet bgs	MW17-04XX03-01- 01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	Well B	Monitoring Well	Approx. 30 feet bgs	WELLB-04XX03- 01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	Well C	Monitoring Well	Approx. 30 feet bgs	WELLC-04XX03- 01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	GW-11	Monitoring Well	Approx. 30 feet bgs	GW11-04XX03-01- 01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	April 2003	RW-11	Monitoring Well	Approx. 30 feet bgs	RW11-04XX03-01- 01- (Analysis Type)	As above

**Baseline Groundwater Sampling**

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Duplicate QA	Groundwater	Bailer/Pump	April 2003	RW-9	Monitoring Well	Approx. 30 feet bgs	RW9-04XX03-02-01- (Analysis Type)	As above
Duplicate QA	Groundwater	Bailer/Pump	April 2003	New MW-10	Monitoring Well	Approx. 30 feet bgs	MW10-04XX03-02-01- (Analysis Type)	As above
Trip Blanks QA	De-ionized Water	Prepared prior to sampling	April 2003	1 per day	N/A	N/A	DB-TB-04XX03	VOCs
Field Blanks QA	De-ionized Water	Prepared prior to sampling	April 2003	2.5% total samples	N/A	N/A	DB-FB-04XX03	VOCs
Equipment Blanks QA	De-ionized Water	Prepared subsequent to sampling	April 2003	5% total samples	N/A	N/A	DB-EB-04XX03	VOCs

**Soil Coring #1**

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	0 – 4 ft bgs	SC-01-0-4	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	4 – 8 ft bgs	SC-01-4-8	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	8 – 12 ft bgs	SC-01-8-12	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	12 – 16 ft bgs	SC-01-12-16	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	16 – 20 ft bgs	SC-01-16-20	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	20 – 24 ft bgs	SC-01-20-24	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	24 – 28 ft bgs	SC-01-24-28	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	28 – 32 ft bgs	SC-01-28-32	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	32 – 36 ft bgs	SC-01-32-36	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 01	Core Location	36 – 40 ft bgs	SC-01-36-40	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	0 – 4 ft bgs	SC-02-0-4	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	4 – 8 ft bgs	SC-02-4-8	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	8 – 12 ft bgs	SC-02-8-12	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	12 – 16 ft bgs	SC-02-12-16	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	16 – 20 ft bgs	SC-02-16-20	Visual Exam



**Soil Coring #1**

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	20 – 24 ft bgs	SC-02-20-24	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	24 – 28 ft bgs	SC-02-24-28	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	28 – 32 ft bgs	SC-02-28-32	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	32 – 36 ft bgs	SC-02-32-36	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 02	Core Location	36 – 40 ft bgs	SC-02-36-40	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	0 – 4 ft bgs	SC-03-0-4	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	4 – 8 ft bgs	SC-03-4-8	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	8 – 12 ft bgs	SC-03-8-12	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	12 – 16 ft bgs	SC-03-12-16	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	16 – 20 ft bgs	SC-03-16-20	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	20 – 24 ft bgs	SC-03-20-24	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	24 – 28 ft bgs	SC-03-24-28	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	28 – 32 ft bgs	SC-03-28-32	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	32 – 36 ft bgs	SC-03-32-36	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 03	Core Location	36 – 40 ft bgs	SC-03-36-40	Visual Exam

**Soil Coring #1**

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	0 – 4 ft bgs	SC-04-0-4	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	4 – 8 ft bgs	SC-04-4-8	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	8 – 12 ft bgs	SC-04-8-12	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	12 – 16 ft bgs	SC-04-12-16	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	16 – 20 ft bgs	SC-04-16-20	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	20 – 24 ft bgs	SC-04-20-24	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	24 – 28 ft bgs	SC-04-24-28	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	28 – 32 ft bgs	SC-04-28-32	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	32 – 36 ft bgs	SC-04-32-36	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 04	Core Location	36 – 40 ft bgs	SC-04-36-40	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	0 – 4 ft bgs	SC-05-0-4	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	4 – 8 ft bgs	SC-05-4-8	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	8 – 12 ft bgs	SC-05-8-12	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	12 – 16 ft bgs	SC-05-12-16	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	16 – 20 ft bgs	SC-05-16-20	Visual Exam

**Soil Coring #1**

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	20 – 24 ft bgs	SC-05-20-24	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	24 – 28 ft bgs	SC-05-24-28	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	28 – 32 ft bgs	SC-05-28-32	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	32 – 36 ft bgs	SC-05-32-36	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 05	Core Location	36 – 40 ft bgs	SC-05-36-40	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	0 – 4 ft bgs	SC-06-0-4	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	4 – 8 ft bgs	SC-06-4-8	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	8 – 12 ft bgs	SC-06-8-12	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	12 – 16 ft bgs	SC-06-12-16	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	16 – 20 ft bgs	SC-06-16-20	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	20 – 24 ft bgs	SC-06-20-24	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	24 – 28 ft bgs	SC-06-24-28	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	28 – 32 ft bgs	SC-06-28-32	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	32 – 36 ft bgs	SC-06-32-36	Visual Exam
Core	Soil	Direct Push	May 2003	Soil Core 06	Core Location	36 – 40 ft bgs	SC-06-36-40	Visual Exam

# Monthly Groundwater Sampling #1

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Grab	Groundwater	Bailer/ Pump	May 2003	RW-9	Monitoring Well	Approx. 30 feet bgs	RW9-05XX03-01-01- (Analysis Type) Note: "Analysis Type" codes are located in the next column)	VOCs (VOC), Ethene/ ethane/ methane (EEM), VFAs (VFA), Iron II (FE), Nitrate (NI), Sulfate (SU), Alkalinity (AL), Microbiological Analyses (MA)
Grab	Groundwater	Bailer/ Pump	May 2003	UDBP-8	Monitoring Well	Approx. 30 feet bgs	UDBP8-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	PZ-4	Monitoring Well	Approx. 30 feet bgs	PZ4-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	MW-3	Monitoring Well	Approx. 30 feet bgs	MW3-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	New MW-10	Monitoring Well	Approx. 30 feet bgs	MW10-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	New MW-11	Monitoring Well	Approx. 30 feet bgs	MW11-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	New MW-12	Monitoring Well	Approx. 30 feet bgs	MW12-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	New MW-13	Monitoring Well	Approx. 30 feet bgs	MW13-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	New MW-14	Monitoring Well	Approx. 30 feet bgs	MW14-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	New MW-15	Monitoring Well	Approx. 30 feet bgs	MW15-05XX03-01-01- (Analysis Type)	As above

# **Monthly Groundwater Sampling #1**

Sample Description				Sample Location				Analysis Type
Sample Type	Media	Collection Type	Planned Date	Location	Type of Location	Depth	ID Number	
Grab	Groundwater	Bailer/ Pump	May 2003	New MW-16	Monitoring Well	Approx. 30 feet bgs	MW16-05XX03-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	New MW-17	Monitoring Well	Approx. 30 feet bgs	MW17-05XX03-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	Well B	Monitoring Well	Approx. 30 feet bgs	WELLB-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	Well C	Monitoring Well	Approx. 30 feet bgs	WELLC-05XX03-01-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	GW-11	Monitoring Well	Approx. 30 feet bgs	GW11-05XX03-01- (Analysis Type)	As above
Grab	Groundwater	Bailer/ Pump	May 2003	RW-11	Monitoring Well	Approx. 30 feet bgs	RW11-05XX03-01- (Analysis Type)	As above
Duplicate QA	Groundwater	Bailer/ Pump	May 2003	RW-9	Monitoring Well	Approx. 30 feet bgs	RW09-05XX03-02-01- (Analysis Type)	As above
Duplicate QA	Groundwater	Bailer/ Pump	May 2003	New MW-01	Monitoring Well	Approx. 30 feet bgs	MW01-05XX03-02-01- (Analysis Type)	As above
Trip Blanks QA	De-ionized Water	Prepared prior to sampling	May 2003	1 per day	N/A	N/A	DB-TB-05XX03	VOCs
Field Blanks QA	De-ionized Water	Prepared prior to sampling	May 2003	2.5% total samples	N/A	N/A	DB-FB-05XX03	VOCs
Equipment Blanks QA	De-ionized Water	Prepared prior to sampling	May 2003	5% total samples	N/A	N/A	DB-EB-05XX03	VOCs

## **Exhibit 5**

### **Community Involvement Documents**



## **SUPERFUND FACT SHEET UPDATE**

### **DISTLER FARM AND DISTLER BRICKYARD SITES WEST POINT, KENTUCKY**

**July, 2003**

#### **INTRODUCTION**

This Superfund Fact Sheet has been prepared by the US Environmental Protection Agency (EPA) in cooperation with the Kentucky Division of Waste Management (KDWM). It has been prepared for the following two reasons:

1. To update the public on the progress of the Long-Term Remedial Action activities at the Distler Farm and Distler Brickyard Sites.
2. To inform the public that a Five Year Review of each site will be conducted shortly. The intent of the reviews is to evaluate the performances of the cleanup measures implemented at the sites to ensure continued protection of human health and the environment.

#### **SITES' BACKGROUND AND HISTORY**

##### **Distler Farm Superfund Site**

The Distler Farm Superfund Site is a little over 13 acres in size and is located near the city of West Point in Jefferson County, Kentucky. It is approximately one mile northeast of the Salt River and Ohio River confluence, and lies within the 10 year flood plain of the Ohio River. The property was being used for recycling and storage of industrial liquid waste when it was discovered in 1977, by EPA.

The Ohio River flooded the area in December 1978, and dumped drums of waste from the site along the nearby Stump Gap Creek.

Following the flood, EPA and KDWM removed more than 800 scattered drums containing chemicals used in paint and varnish industries from the property and adjoining area. During the emergency action, several locations of buried waste were discovered on the property. Approximately 120 drums and more than 2,600 small containers of hazardous materials were excavated from the site and disposed of at approved facilities. Based on subsequent site studies, it was determined that the groundwater and soil were contaminated with volatile organic compounds (VOCs), such as toluene and benzene. Heavy metals, including chromium and lead were also found in the groundwater and soil.

Construction activities for permanent cleanup began at the site in 1988. During the process, additional drums were uncovered. The drums primarily contained medical and laboratory waste, herbicides and solvents. These, as well as more contaminated soil, were removed and sent outside the State for proper disposal. The affected area was backfilled with clean dirt and seeded with grass. Wells were installed in 1989 to extract contaminated water which has been trucked since then, periodically, to the Metropolitan Sewer District's facility for treatment and disposal. Based on the scheduled laboratory analyses of the extracted water samples, most of the contaminants in the groundwater have been reduced to safe levels by the cleanup activities. The remaining compounds will continue to be addressed until they reach acceptable concentrations. In addition to the monitoring wells, several private wells in the area have been tested for site related contaminants a number of times. The tests have not indicated that the wells have

## **UP-COMING FIVE-YEAR REVIEWS**

EPA and the State will conduct a five-year review of the cleanup activities at these two sites between now and mid-September 2003. The reviews will critically examine how effective the remedies implemented at each of the sites have been, and if the remedies will continue to protect human health and the environment.

Two previous five year reviews were conducted on the Distler Farm Site. They were completed in September 1993, and September 1998, respectively. Both reports concluded that the remedy implemented at the site was providing human health and environmental protection adequately. The only previous review of the Distler Brickyard remedy was conducted in September 1998. The review concluded that the remedy was performing effectively, but that the contaminant recovery process was slow. Therefore, it recommended that the process be evaluated and modified for improvement.

As part of the current reviews, we are seeking your opinion on the cleanup activities conducted at the sites. We will interview a number of people by telephone, including nearby residents, local officials, and others to hear their views or concerns about the sites. If you would like to participate in this community involvement activity, please call 1-800-435-9233 and speak with Linda Starks, EPA Community Involvement Coordinator by July 31, 2003.

Once all data and public input have been received and evaluated, a Five-Year Review Report will be prepared for each site. Copies will be placed in the sites' Information Repository.

These reviews are scheduled to be completed by September 30, 2003. The next 5-year review should occur in 2008.

## **NEED FURTHER INFORMATION?**

If you have technical questions about these two sites, please contact:

**Femi Akindele**                      **404-562-8809**  
EPA Remedial Project Manager  
US EPA, Region 4  
61 Forsyth Street, SW  
Atlanta, GA 30303

**Ken Logsdon**                      **502-564-6716**  
State Project Manager  
Kentucky Division of Waste Management  
18 Reilly Road  
Frankfort, KY 40601

For additional copies of this fact sheet or other general information contact:

**Linda Starks**                      **800-435-9233**  
Community Involvement Coordinator  
US EPA, Region 4  
61 Forsyth Street, SW  
Atlanta, GA 30303

## **INFORMATION REPOSITORY**

A copy of various documents, data reports and other site related information have been made available to the public and placed in the:

West Point City Hall  
5909 Elm Street  
West Point, KY 40177



United States Environmental Protection Agency

Region 4: AL, FL, GA, KY, MS, NC, SC, TN  
Office of External Affairs

Sam Nunn Atlanta  
Federal Center

61 Forsyth St. SW  
Atlanta, GA 30303-3104



# Environmental News

PHONE: (404) 562-8327

FAX: (404) 562-8335

**THE U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA) WILL CONDUCT FIVE-YEAR REVIEWS OF THE DISTLER FARM SITE IN WEST POINT, JEFFERSON COUNTY, KENTUCKY AND DISTLER BRICKYARD SITE IN WEST POINT, HARDIN COUNTY, KENTUCKY**

The U.S. Environmental Protection Agency (EPA) today announces that two separate five-year reviews are being conducted for the cleanup at the Distler Farm and Distler Brickyard sites. The five year reviews will evaluate the remedies implemented at the sites and determine if they are still protective of human health and the environment. The remedies implemented at both sites included: soil excavation and treatment, groundwater extraction/treatment/discharge and monitoring. Presently, both sites are undergoing the process of final groundwater clean up known as Long-Term Remedial Action. Previous reviews concluded that the remedial activities have remained effective.

The Distler Farm site is a 13-acre property that was used for industrial waste storage. Studies of the site indicated that soil and groundwater were contaminated with volatile organic compounds (VOCs), such as toluene and benzene, and heavy metals such as chromium and lead. Approximately 3,000 people reside within four miles of the site. The Distler Brickyard site covers approximately 3 acres and is a portion of an abandoned brick manufacturing plant. In 1976, the Kentucky Liquid Recycling Inc. leased and began to use the property for storage of waste. During the initial inspection, approximately 2,300 drums were found at this site. Most of the drums contained chemicals, sludge, and solids which had deteriorated causing harm to the ground surface and surrounding environment. Approximately 70,000 people depend on private wells within a 3-mile radius for drinking water. Permanent cleanup began in 1988 at both sites.

Additional information about the sites may be obtained by contacting Linda Starks, EPA Community Involvement Coordinator at 1-800-435-9233 or Femi Akindele, EPA Remedial Project Manager at 404-562-8809.

-0- August 6, 2003

CONTACT: Kathy Armstrong, EPA Media Relations, (404) 562-8225



A Five-Year Review is being conducted of the clean up activities taken at the Distler Farm and Distler Brickyard Sites (Jefferson County) in West Point, Kentucky. A copy of the report will be placed in the Administrative Record & Information Repository files located in the EPA Record Center, 11th Floor, 81 Forsyth Street, SW, Atlanta, GA 30303, and the West Point City Hall, 5909 Elm Street, West Point, KY.

Permanent clean-up began in 1988 at Distler Farms and Distler Brickyard Sites. The remedies implemented at both Sites included: soil excavation and treatment; groundwater extraction/treatment/discharge/monitoring. To enhance cleanup at Distler Brickyard Site, certain materials were injected into the most contaminated areas to degrade the contaminants. Based on samples taken of the groundwater, it appears that the selected remedy has removed some of the contaminants, and the remedy remains protective of human health and the environment.

The Five Year Review process is evaluating the remedies implemented at the site and determine if they are still protective of human health and the environment. Two previous reviews occurred in 1993 and 1998. Both reviews concluded that the remedial activities at the Site remained effective. The current review will evaluate present Site conditions.

EPA will also conduct a number of telephone interviews with nearby residents, local officials, state officials, and others to obtain their opinion on the clean up process. If you would like to speak with us about this Site, please call Linda Starks, EPA Community Involvement Coordinator, at 1-800-435-9233 or 404-562-8487. If you have any technical questions, please contact Femi Akindele, EPA Site Project Manager at 404-562-8808.

**Distler Brickyard  
5-Year Review Questionnaire**

**West Point, Kentucky**

Do you live near the Site? **Yes, 1 mile from Brickyard.** If yes, how long? **58 years**

Are you familiar with EPA activities over the past years? **Yes**

What is your overall impression of the project? **Everything seems fine.**

Overall, have you been pleased or displeased with cleanup actions at this Site? **Pleased.**

What effects, if any, have site operations had on the surrounding community? **None**

Do you still have any concerns regarding EPA clean up activities of the Site? **No.**

Do you think you have been kept adequately informed about clean up activities at the Site?  
**Yes.**

Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details. **No.**

Is there someone else that you would like to recommend we contact for more information? **No.**

Do you have any suggestions that EPA can implement to improve communication with the public? **No.**

**Interview Conducted by: Linda Starks  
Date Conducted: August 19, 2003**

**Distler Brickyard  
5-Year Review Questionnaire**

**West Point, Kentucky**

Do you live near the Site? **Yes, about 3 miles.** If yes, how long? **7 years and husband has lived there 31 years**

Are you familiar with EPA activities over the past years? **Yes**

What is your overall impression of the project? **Looks cleaner but there is bad odor coming from the site when you pass by. It is less of an eye sore.**

Overall, have you been pleased or displeased with cleanup actions at this Site? **Pleased.**

What effects, if any, have site operations had on the surrounding community? **None**

Do you still have any concerns regarding EPA clean up activities of the Site? **Yes. By the site being so close to the river we are wondering about the smell and how that could effect the air.**

Do you think you have been kept adequately informed about clean up activities at the Site? **Yes. The flyer we received two months ago help me learn more about the site.**

Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details. **No.**

Is there someone else that you would like to recommend we contact for more information? **No.**

Do you have any suggestions that EPA can implement to improve communication with the public? **No, the literature was sufficient.**

**Interview Conducted by: Linda Starks  
Date Conducted: August 19, 2003**

**Distler Brickyard  
5-Year Review Questionnaire**

**West Point, Kentucky**

Do you live near the Site? **Yes, about 1 mile.** If yes, how long? **28 years**

Are you familiar with EPA activities over the past years? **Yes**

What is your overall impression of the project? **OK**

Overall, have you been pleased or displeased with cleanup actions at this Site? **Pleased.**

What effects, if any, have site operations had on the surrounding community? **None**

Do you still have any concerns regarding EPA clean up activities of the Site? **No, not Distler Farm, but there is an Oil Refinery on Dixie Hwy and Hwy 44 that has terrible odors coming from the old tanks. The community feels that the odor is so bad it attributes to headaches (especially when it rains).**

Do you think you have been kept adequately informed about clean up activities at the Site? **Yes.**

Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details. **No.**

Is there someone else that you would like to recommend we contact for more information? **No.**

Do you have any suggestions that EPA can implement to improve communication with the public? **It would be nice if EPA could come to occasional Council Meetings to keep the neighborhood abreast of any activities.**

**Interview Conducted by: Linda Starks  
Date Conducted: August 19, 2003**

## **Distler Brickyard 5-Year Review Questionnaire**

**West Point, Kentucky**

Do you live near the Site? **Yes, about 1 ½ To 2 miles.** If yes, how long? **20 years**

Are you familiar with EPA activities over the past years? **Yes**

What is your overall impression of the project? **They said they cleaned up the site, so its OK**

Overall, have you been pleased or displeased with cleanup actions at this Site? **Pleased.**

What effects, if any, have site operations had on the surrounding community? **None**

Do you still have any concerns regarding EPA clean up activities of the Site? **Yes. There have been several deaths that could have or have not been related to the site.**

Do you think you have been kept adequately informed about clean up activities at the Site? **No. When the site was first being cleaned up, they sampled the site more. And even though the site has been cleaned up, the community still need to know what's going on.**

Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details. **No events really. I have noticed there were hunters on the property.**

Is there someone else that you would like to recommend we contact for more information? **Yes. Beverly Jeffries (owns a business) seems to have had some concern. Also the City Council which consists of Eric Duvall (Mayor), Ted Akins (President City Council), Carl Hall, Billy aski, Marion Applegate, and Vernon Curles.**

Do you have any suggestions that EPA can implement to improve communication with the public? **Yes, EPA could come back and maybe come to a Council Meeting (which is held the 2<sup>nd</sup> Monday of each month) and let us know what's going on, good or bad. Also there could be a newsletter discussing the site. I know, I sat on the city council for 20 years and occasionally, there are still questions asked about Distler Farm and Brickyard.**

**Interview Conducted by: Linda Starks**  
**Date Conducted: August 19, 2003**

**Distler Brickyard  
5-Year Review Questionnaire**

**West Point, Kentucky**

Do you live near the Site? **Yes about 3 miles.** If yes, how long? **20 years**

Are you familiar with EPA activities over the past years? **Yes**

What is your overall impression of the project? **Everything seems to be fine.**

Overall, have you been pleased or displeased with cleanup actions at this Site? **Pleased.**

What effects, if any, have site operations had on the surrounding community? **None**

Do you still have any concerns regarding EPA clean up activities of the Site? **No.**

Do you think you have been kept adequately informed about clean up activities at the Site?  
**Yes. I received a flyer about a month ago.**

Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details. **No.**

Is there someone else that you would like to recommend we contact for more information? **No.**

Do you have any suggestions that EPA can implement to improve communication with the public? **None**

**Interview Conducted by: Linda Starks  
Date Conducted: August 19, 2003**

**Distler Brickyard  
5-Year Review Questionnaire**

**West Point, Kentucky**

Do you live near the Site? **Yes** If yes, how long? **66 years**

Are you familiar with EPA activities over the past years? **Yes**

What is your overall impression of the project? **At first the project was of concern, but when they said it was clean there was not much concern. She still drinks bottled water though.**

Overall, have you been pleased or displeased with cleanup actions at this Site? **Pleased, but still concerned.**

What effects, if any, have site operations had on the surrounding community? **None**

Do you still have any concerns regarding EPA clean up activities of the Site? **Still concerned about cancer risks since her mother died in 1980 and she has cancer also. A lot of people in the community died from cancer.**

Do you think you have been kept adequately informed about clean up activities at the Site? **Yes. There have been no problems.**

Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details. **No.**

Is there someone else that you would like to recommend we contact for more information? **No.**

Do you have any suggestions that EPA can implement to improve communication with the public? **None**

**Interview Conducted by: Linda Starks  
Date Conducted: August 4, 2003**